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ABSTRACT

Designed as a self-study text for enlisted personnel of the Navy and Naval Reserve, this rate training manual presents information that is directly related to the professional standards for advancement to Petty Officer Third Class and Petty Officer Second Class in the Tradevman (TD) rating. (Tradevmen install, repair, modify, and maintain audio-visual aids; perform organizational and intermediate level maintenance on training devices; operate and maintain equipment used in conjunction with training devices; operate training devices and ancillary equipment to train and maintain proficiency of individuals and/or terms; assist in development, operation, and/or improvement of programs of supported activities; and construct, devise, or obtain training aids. Assignment billets include fleet submarine and fleet ballistic missile submarine trainers, radar bomb scoring units, and others.) Topical sections of the manual are as follows: administration and supply; supervision of maintenance and operations; principles of air conditioning; simulator motion systems; closed circuit TV: optics, cameras, control units, transmission; closed circuit TV: receivers, maintenance, and applications; introduction to digital simulator systems; and digital systems troubleshooting. A listing of general purpose digital computers incorporated in COG'20' training equipment is appended. The manual is indexed. The nonresident career course which follows the main manual consists of assignments and technical questions based on the occupational standards. (BL)

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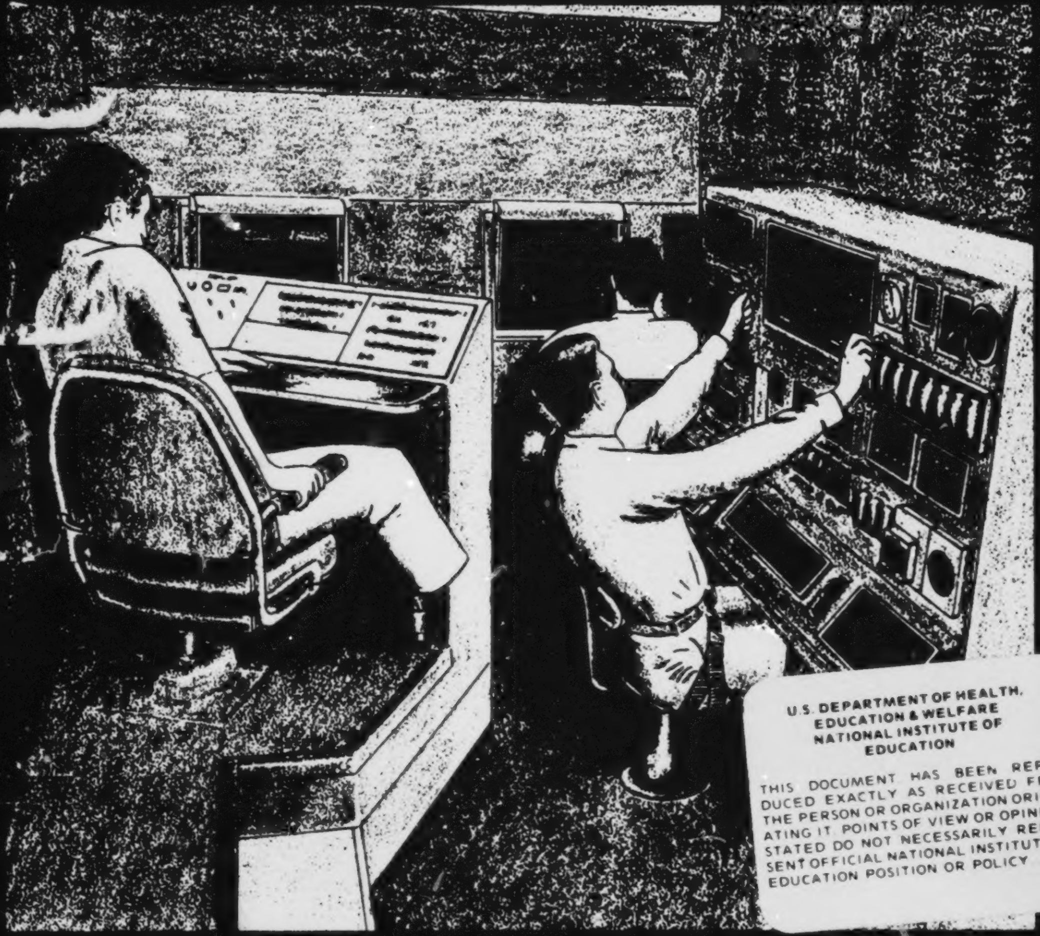

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TRADEVMAN 1&C

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NAVAL EDUCATION AND TRAINING COMMAND

RATE TRAINING MANUAL AND NONRESIDENT CAREER COURSE

NAVEDTRA 10378-D

PREFACE

This Rate Training Manual is one of a series of training manuals prepared for enlisted personnel of the Navy and Naval Reserve who are working in the Tradevman (TD) rating. As indicated by the title, this manual is based upon the professional occupational standards for TD1 and TDC.

The associated TD 1 & C nonresident career course is included as the last section of this manual. Technical questions based upon occupational standards are provided in the assignments. Full use of these study aids will greatly assist the TD2 and TD1 in preparing for the advancement examination. This manual and the attendant nonresident career course are also valuable aids as review sources for those preparing for TDCS and TDCM.

This training manual was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Technical review of the manuscript was provided by personnel in TD schools, NATTC, Orlando, and various fleet activities.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

TRADEVMAN RATING

This Rate Training Manual is designed as a self-study text for use by those personnel of the Navy and Naval Reserve who are preparing to meet the professional (technical) qualifications for advancement to Petty Officer Third Class and Petty Officer Second Class in the Tradevman (TD) rating. A second purpose of this manual is the improvement of job skills. This purpose is achieved through use of the manual as a study aid in conjunction with on-the-job training.

Minimum professional requirements for advancement in all ratings are listed in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068 (Series). Formerly entitled the *Manual of Qualifications for Advancement*, NAVPERS 18068 will be referred to in this training manual as the *Occupational Standards Manual*.

The occupational standards upon which this Rate Training Manual is based are those appearing in Series D of NAVPERS 18068. It should be kept in mind that any subsequent changes to the *Occupational Standards Manual* may not be reflected in the information presented in this training manual. As this manual does not cover the occupational standards in complete depth, extensive use should be made of other publications referred to throughout this training manual.

The Nonresident Career Course for this Rate Training Manual has been included at the end of the text material. It is to assist you in the training required to fulfill your job requirements, and it will be of benefit when you are preparing for the Navy-wide advancement examinations. The answer sheets, referred to as IKOR (immediate knowledge of response) sheets, are a separate package and are not included with the Rate Training Manual. A separate errata sheet may be included with this training package if there are changes to the text material of the Rate Training Manual or to the Nonresident Career Course. Read the preliminary pages of the Nonresident Career Course thoroughly for complete instructions before you proceed with the course.

Since senior TDs are largely occupied with planning, supervision, and training, this manual has been designed for maximum development of these skills. A manual of this type cannot present all the detailed knowledge which is required in every duty assignment. Particular details should always be checked in applicable manuals or instructions.

The remainder of this chapter contains information that will help you in preparing for advancement. It is strongly recommended that you study this chapter carefully before beginning intensive study of the remainder of this Rate Training Manual.

ENLISTED RATING STRUCTURE

The present enlisted rating structure includes two types of ratings: general ratings and service ratings.

GENERAL RATINGS are designed to provide paths of advancement and career development. A general rating identifies a broad occupational field of related duties and functions requiring similar aptitudes and qualifications. General ratings provide the primary means used to identify billet requirements and personnel qualifications. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

Subdivisions of certain general ratings are identified as SERVICE RATINGS. These service ratings identify areas of specialization within the scope of a general rating. Service ratings are established in those general ratings in which specialization is essential for efficient utilization of personnel. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

NAVY ENLISTED CLASSIFICATION CODES

Section II of the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards* is the official manual for NEC (Navy Enlisted Classification) Code identification of enlisted personnel and requirements. The NEC structure supplements the enlisted rating structure in identifying personnel and billets in manpower authorizations. NEC codes reflect special knowledges and skills that identify personnel and requirements when the rating structure is insufficient by itself for manpower management purposes.

The skills reflected by NECs are an important tool in assigning TDs to a new duty station. This will be covered in more detail in Chapter 2 of this manual.

NECs are grouped under one of the following categories:

1. Entry Series, which consist of Rating Conversion and Occupational Area–Defense Grouping (DG) NECs.

a. Rating Conversion NECs identify aptitudes and qualifications not discernible from rates alone, and are assigned to identify petty officers or identified strikers who are in training for change of rating or status under approved programs. The rating conversion NEC used for TDs is TD-7599 (Tradevman Basic).

b. Occupational Area–Defense Grouping (DG) NECs relate to groups of ratings for which there is an identification requirement. The DG NEC code used for TDs is DG-9710 (Electronic Equipment Repairman). USN and USNR personnel in pay grades E-1 through E-3 (not already "rating associated" by HM or DT apprenticeship rates, or by striker identification) must be assigned an appropriate DG NEC which identifies and indicates that these individuals have received training, are in training, or have aptitude for training in the areas identified by the DG code.

2. Special Series consists of NECs which are not related to any particular rating, but are used to identify billet requirements not sufficiently identified by rates, and identify the personnel who are qualified to be distributed and detailed to fill these requirements. Examples of this special series are 9583 (Locksmith); 9585-9588 (Career Counselor); and 9545 (Security Guard).

3. Rating Series, which relate to specific ratings, and are used to identify billet requirements not sufficiently identifed by rates, and identify personnel who are qualified to be distributed and detailed to fill these requirements.

TD NECs

TD-7514 Surface Training
Equipment Technician

Operates and maintains simulation equipment associated with propulsion control, tactical maneuvering, combat information centers, antisubmarine warfare, electronic countermeasures, radar, sonar, loran, and other operations involving searching, plotting, and tracking by electronics means.

TD-7523 Operational Flight/Weapons
System Trainer Technician

Operates and maintains simulators used to train pilots and/or crews in operation and tactics procedures employed in all types of aircraft.

TD-7553 Submarine Training
Equipment Technician

Operates and maintains simulators used to train personnel in operation and tactics procedures employed in all types of submarines.

THE TD RATING

The *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards* states that Tradevmen install, repair, modify, and maintain audio/visual aids; perform organizational and intermediate level maintenance on training devices; operate and maintain equipment used in conjunction with training devices; operate training devices and ancillary equipment to train and maintain the proficiency of individuals and/or teams; assist in development, operation, and/or improvement of training programs of supported activities; and construct, devise, or obtain training aids.

The TD1 must be qualified to supervise and direct training inspections; maintain logs and records and prepare reports; order and identify publications; maintain current shop files of directives and other publications; identify and order parts, tools, and equipment; maintain inventory records; and use schematic diagrams, drawings, and charts in troubleshooting and correcting material failures.

In addition to the above listed requirements for TD1, the TDC must be qualified to review and evaluate completed inspection forms and reports; analyze reports of discrepancies and malfunctions and determine corrective action; schedule and assign workload; determine repair procedures for training devices; interpret directives from higher authorities; and maintain quality control of work performed.

A wide variety of assignments is available to the Tradevman. In addition to the various types of maintenance activities to which lower rated personnel are assigned, the TD1 and TDC are eligible for assignment to instructor duty as well as a number of other desirable billets. Most of these billets are under the management control of BUPERS and are directly associated with training. Others are associated with research, testing, or evaluation. Some of the billets to which the TD1 and TDC may be assigned are described briefly as follows:

1. Fleet submarine and fleet ballistic missile submarine trainers: Operating and maintaining trainers used to train submarine crews. These trainers are located at New London, Connecticut; Charleston, South Carolina; Mare Island, California; Pt. Loma, California; and Pearl Harbor, Hawaii.

2. Radar bomb scoring unit: Evaluation of tactical bombing operations. They are located at Pinecastle, Florida; Sigonella, Italy; Seattle, Washington; and Fallon, Nevada.

3. Naval Education and Training Support Centers and Detachments: Assist in the

procurement, installation, evaluation, and maintenance of training equipment. The support centers and detachments are located in San Diego, California; Pensacola, Florida; Norfolk, Virginia; and Pearl Harbor, Hawaii.

4. Fleet Aviation Specialized Operational Training Groups: Operating and maintaining instrument trainers, operational flight trainers, weapon system trainers and radar trainers.

5. Miscellaneous billets: Instructor duty at the TD and the Avionics schools located at Memphis, Tennessee. Duty as a Navy recruiter or at a recruit training center. Senior TDs are assigned as the technical writers for the Tradevman Rate Training Manuals and as the exam writers for the Tradevman fleet-wide rating exams. Both are perpared at Pensacola, Florida.

The above list of billets is not a complete listing of all the duty assignments available to a TD. Billets and assignments will vary with the needs of the Navy. More detailed information on the billets available can be provided by the technical assistant to the TD rating control officer in the Bureau of Naval Personnel (PERS-5V(A)). The technical assistant is normally a Master Chief Tradevman.

ADVANCEMENT

By this time, you are probably well aware of the personal advantages of advancement–higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. By this time, also, you have probably discovered that one of the most enduring rewards of advancement is the training you acquire in the process of preparing for advancement.

The Navy also profits by your advancement. Highly trained personnel are essential to the functioning of the Navy. By advancement, you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist, and thus make far-reaching contributions to the entire Navy; and second, you become more valuable as a person who can supervise, lead, and train others.

Since you are studying for advancement to PO1 or CPO, you are probably already familiar with the requirements and procedures for advancement. However, you may find it helpful to read the following sections. The Navy does not stand still. Things change all the time, and it is possible that some of the requirements have changed since the last time you went up for advancement. Furthermore, you will be responsible for training others for advancement; therefore, you will need to know the requirements in some detail.

HOW TO QUALIFY FOR ADVANCEMENT

To qualify for advancement, a person must:

1. Have a certain amount of time in grade.

2. Complete the required Rate Training Manual either by demonstrating a knowledge of the material in the manual by passing a locally prepared and administered test, or by passing the Nonresident Career Course based on the Rate Training Manual.

3. Demonstrate the ability, when required by command policy, to perform applicable tasks in the Personnel Advancement Requirement (PAR) Program.

4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated they consider you capable of performing the duties of the next higher rate.

5. Demonstrate KNOWLEDGE by passing a written examination on the requirements reflected in the occupational standards.

Remember that the requirements for advancement can change. Check with your educational services office to be sure you know the most recent requirements.

When you are training lower rated personnel, it is a good idea to point out that advancement is not automatic. Meeting all the requirements makes a person ELIGIBLE for advancement, but it does not guarantee his advancement. Such factors as the score made on the written examination, length of time in service, performance marks, and quotas for the rating enter into the final determination of who will actually be advanced.

The final selection for Chief Petty Officer is made by a regularly convened selection board.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the requirements for advancement, work on the PAR Program, study the required Rate Training Manuals, and study other material that is required. You will need to be familiar with the following:

1. *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068 (Series).
2. Personnel Qualification Standard (PQS) for the equipment/system and rating assigned.
3. Personnel Advancement Requirement (PAR) Program, NAVPERS 1414/4.
4. *Bibliography for Advancement Study*, NAVEDTRA 10052 (Series).
5. Applicable Rate Training Manuals and their companion Nonresident Career Courses.

Collectively, these documents make up an integrated training package tied together by the occupational standards. The following paragraphs describe these materials and give some information on how each one is related to the others.

Occupational Standards

The *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068 (Series), contains the standards which state the Navy's minimum requirements for enlisted skills. These standards form the basis for the training, advancement, and distribution of enlisted personnel. The standards are based on general responsibility levels, with the more routine tasks placed at the lower paygrades. The more difficult tasks and tasks requiring additional experience or involving supervision are placed at progressively higher paygrades.

The standards, which encompass the Navy's minimum requirements for enlisted skills, are divided into the two following categories:

1. Naval Standards. These standards include skills which are not specifically rating oriented. They are applicable to all rates and ratings. Naval Standards are stated as knowledge requirements in that they represent basic things (military requirements, naval tradition, personnel safety, etc.) which should be known, and not necessarily done as a matter of routine.

2. Occupational Standards. These standards define the tasks required of specified rates and ratings. Unlike the old advancement quals, which contained practical factors and knowledge factors, Occupational Standards are expressed as task statements only. The concept is that the task statements define what enlisted personnel must do in their rate or rating and that the knowledge required to perform a task is inherent to the proper performance of the task.

Both the Naval Standards and the Occupational Standards are divided into standard topic titles (standardized grouping of similar subject matter). Then, under each topic title of the Naval Standards is a listing of knowledge requirements, and under each topic title of the Occupational Standards is a listing of task statements.

The *Occupational Standards Manual* has grouped all ratings under their respective Occupational Field. The Occupational Standards for Tradevman are listed under Occupational Field 11, (Weapons Systems Support). Keep in mind that the *Occupational Standards Manual* is changed more frequently than Rate Training Manuals are revised. It is essential that the standards reflect current requirements of fleet and shore operations, and that new fleet-wide technical, operational, and procedural developments be included. For these reasons, the standards are continually under evaluation. Although there is an established schedule for revisions, urgent changes may be made at any time. These revisions are issued in the form of changes to NAVPERS 18068 (Series). Therefore, never trust any set of Occupational Standards until you have checked the change number against an up-to-date copy of the *Occupational Standards Manual.*

In training others for advancement, emphasize the following three points about the Occupational Standards:

1. The standards are the MINIMUM requirements for advancement. Personnel who study more than the required minimum will have a great advantage when they take the written examination for advancement.

2. Each standard has a designated rate level–chief, first class, second class, or third class. You are responsible for the knowledge required to perform all tasks specified for the rate level to which you are seeking advancement, and for all tasks specified for lower rate levels.

3. The written examination for advancement will test your knowledge and understanding of the requirements reflected in the Occupational Standards.

Personnel Advancement Requirement (PAR) Program

The PAR program was initiated by the Bureau of Naval Personnel to replace the practical factors requirement of the "Quals" manual.

The former "quals," as set forth in the *Manual of Qualifications for Advancement* (NAVPERS 18068-C), were stated in terms of practical factors and knowledge factors. The new occupational standards, as stated in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards* (NAVPERS 18068-D), are presented only as task statements–things to be done in a rating. This new format of the occupational standards does not lend itself to the practical factor checkoff list concept of the Record of Practical Factors (NAVEDTRA 1414/1). As a result, a new form and concept of determining eligibility for advancement have been developed. The Personnel Advancement Requirement (PAR) form (NAVPERS 1414/4) replaces the Record of Practical Factors (NAVEDTRA 1414/1). This new system is designed to be more realistic in approach and operation by allowing a command to evaluate the overall abilities of an individual in a day-to-day work situation and eliminate the need to complete a mandatory, lengthy, and detailed checkoff list.

Under the new program, candidates for E-3, E-8, and E-9 are exempt from the PAR requirement. The E-3 apprenticeships are so broad that they make the development of a single PAR impractical. The E-8 and E-9 are exempt from the PAR Program as there are other means of selection for advancement to these paygrades.

Each rating PAR lists the requirements for advancement to paygrade E-4 through E-7 in one pamphlet. Each PAR contains descriptive information, instructions for administration, special rating requirements (physical, citizenship, security clearance, etc.) and advancement requirements in the following sections:

Section I–Administration Requirements

Section II–Formal School and Training Requirements

Section III–Occupational and Military Ability Requirements

Section I (Administration Requirements) contains the individual's length of service, time in rate, and a place to checkoff that the individual has passed the E-4/E-5 Military Leadership Examination.

Section II (Formal Schools and Training Requirements) contains a checkoff entry for the individual having completed the Military Requirements Rate Training Manual and the applicable Rate Training Manual for the individual's rating.

Section III (Occupational and Military Ability Requirements) is a checkoff list of task statements. Items in this section are to be interpreted broadly and do not demand actual demonstration of the item or completion of an alternate local examination, although demonstration is a command prerogative. Individuals are evaluated on their ability to perform the task by observation of ability in related areas, training received, or, if desired, by demonstration.

There is currently a pilot program which includes the PQS watch station qualifications and preventive maintenance actions as a separate section of the PAR form. Under this program section III (Occupational and Military Abilities) lists those task statements required of the rating which are not reflected in the PQS qualifications. As PQS qualifications are developed, and if the pilot program is implemented, PAR forms will be revised to reflect the PQS requirements.

PAR forms are stocked in the Navy Supply system and are listed in the Navy Stock List of Publications and Forms, Section I, NAVSUP Publication 2002.

Personnel Qualification Standards

Personnel Qualification Standards (PQS), described in OPNAV Instruction 3500.34, are presently being utilized to provide guidelines in preparing for advancement and qualification to operate specific equipment and systems. They are designed to support the advancement requirements as stated in the *Occupational Standards Manual*.

The occupational standards and personnel advancement requirements are stated in broad terms. Each PQS is much more specific in its questions that lead to qualification. It provides an analysis of specific equipment and duties, assignments, or responsibilities which an individual or group of individuals (within the same rating) may be called upon to carry out. In other words, each PQS provides an analysis of the complete knowledge and skills required of that rating tied to a specific weapon system (aircraft and/or individual systems or components).

Each qualification standard has four main subdivisions in addition to an introduction and a glossary of PQS terms. They are as follows:

100 Series–Theory

200 Series–System

300 Series–Watchstations (duties, assignments or responsibilities)

400 Series–Qualification cards

The PQS introduction explains the complete use of the qualification standard in terms of what it will mean to the user as well as how to use it.

The Theory (100 Series) section specifies the theory background required as a prerequisite to the commencement of study in the specific equipment or system for which the PQS was written. These fundamentals are normally taught in the formal schools (Preparatory, Fundamentals, and Class A) phase of an individual's training. However, if the individual has not been to school, the requirements are outlined and referenced to provide guidelines for a self-study program.

The Systems (200 Series) section breaks down the equipment or systems being studied into functional sections. PQS items are essentially questions asked in clear, concise statement (question) form and arranged in a standard format. The answers to the questions must be extracted from the various maintenance manuals covering the equipment or systems for which the PQS was written. This section asks the user to explain the function of the system, to draw a simplified version of the system from memory, and to use this drawn schematic or the schematic provided in the maintenance manual while studying the system or equipment. Emphasis is given to such areas as maintenance management procedures, components, component parts, principles of operation, system interrelations, numerical values considered necessary to operation and maintenance, and safety precautions.

The Watchstation (300 Series) section includes questions regarding the procedures the individual must know to operate and maintain the equipment or system. A study of the items in the 200 series section provides the individual with the required information concerning what the system or equipment does, how it does it, and other pertinent aspects of operation. In the 300 series section, the questions advance the qualification process by requiring answers or demonstrations of ability to put this knowledge to use or to cope with maintenance of the system or equipment. Areas covered include normal operation; abnormal or emergency operation; emergency procedures which could limit damage and/or casualties associated with a particular operation; operations that occur too infrequently to be considered mandatory performance items; and maintenance procedures/instructions such as checks, tests, repair, replacement, etc.

The 400 Series section consists of the qualification cards. These cards are the accounting documents utilized to record the individual's satisfactory completion of items necessary for becoming qualified in duties assigned. Where the individual starts in completing a standard, will depend on his assignment within an activity. The complete PQS should be given to the individual being qualified so that he can utilize it at every opportunity to become fully qualified in all areas of his rating and the equipment or system for which the PQS was written. Upon transfer to a different activity, each individual must requalify. The answers to the questions asked in the qualification standards may be given orally or in writing to the supervisor, the branch or division officer, and the maintenance officer as required to certify proper qualification.

Bibliography for Advancement Study, NAVEDTRA 10052

Bibliography for Advancement Study, NAVEDTRA 10052 (Series), is a very important publication for anyone preparing for advancement. This publication/bibliography lists required and recommended Rate Training Manuals and other reference material to be used by personnel working for advancement. NAVEDTRA 10052 (Series) is revised and issued each year by the Naval Education and Training Support Command. Each revised edition is identified by a letter following the NAVEDTRA number; be SURE you have the most recent edition.

The required and recommended references are listed by rate level in NAVEDTRA 10052 (Series). It is important to remember that you are responsible for all references at lower rate levels, as well as those listed for the rate to which you are seeking advancement.

Rate Training Manuals that are marked with an asterisk (*) in NAVEDTRA 10052 (Series) are MANDATORY at the indicated rate levels. A mandatory training manual may be completed by (1) passing the appropriate Nonresident Career Course based on the mandatory training manual; (2) passing locally prepared tests based on the information given in the mandatory training manual; or (3) in some cases, successfully completing an appropriate Navy school.

When training personnel for advancement, do not overlook the section of NAVEDTRA 10052 (Series) which lists the required and recommended references relating to the military requirements for advancement. All personnel must complete the mandatory military requirements training manual for the appropriate rate level before they can be eligible to advance. Also, in addition to the mandatory references, make sure that the personnel working for advancement study the references listed as recommended in NAVEDTRA 10052 (Series).

Rate Training Manuals

There are two general types of Rate Training Manuals. Rate Training Manuals such as this one are prepared for most enlisted rates and ratings, giving information that is directly related to the professional standards for advancement. Subject matter manuals give information that applies to more than one rating.

Rate Training Manuals are revised from time to time to bring them up to date technically. The revision of a Rate Training Manual is identified by a letter following the NAVEDTRA number. You can tell whether a Rate Training Manual is the latest edition by checking the

NAVEDTRA number (and the letter following the number) in the most recent edition of *List of Training Manuals and Correspondence Courses*, NAVEDTRA 10061 (Series). NAVEDTRA 10061 is actually a catalog that lists current training manuals, enlisted nonresident career courses, and officer correspondence courses; you will find this catalog useful in planning your study program.

Rate Training Manuals are designed for the special purpose of helping naval personnel prepare for advancement. By this time, you have probably developed your own way of studying these manuals. Some of the personnel you train, however, may need guidance in the use of Rate Training Manuals. Although there is no single "best" way to study a training manual, the following suggestions have proved useful for many people:

1. Study the occupational standards for your rate before you study the training manual, and refer to them frequently as you study. Remember, you are studying the training manual primarily to meet these occupational standards.

2. Set up a regular study plan. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the training manual intensively, get acquainted with the entire manual. Read the preface and the table of contents. Check through the index. Thumb through the manual without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a clear picture of the scope and content of the manual.

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit–it may be a chapter, a section of a chapter, or a subsection. The amount of material you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying each unit, write down questions as they occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, ask yourself some questions. Does this information tie in with past experience? Or is this something new and different? How does this information relate to the requirements for advancement?

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without referring to the training manual, write down the main ideas you have learned from studying this unit. Do not just quote the manual. If you cannot give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use Nonresident Career Courses whenever you can. The Nonresident Career Courses are based on Rate Training Manuals or other appropriate texts. As mentioned before, completion of a mandatory Rate Training Manual can be accomplished by passing a Nonresident Career Course based on the training manual. You will probably find it helpful to take other Nonresident Career Courses, as well as those based on mandatory training manuals. Taking a Nonresident Career Course helps you to master the information given in the training manual, and also gives you an idea of how much you have learned. Most officer correspondence courses are available to enlisted personnel also.

ADVANCEMENT OPPORTUNITIES FOR PETTY OFFICERS

Making Chief is not the end of the line as far as advancement is concerned. Advancement to Senior Chief (E-8), Master Chief (E-9), Chief Warrant Officer, and Commissioned Officer are among the opportunities that are available to qualified petty officers. These special paths of advancement are open to personnel who have demonstrated outstanding professional ability, the highest order of leadership and military responsibility, and unquestionable moral integrity.

SENIOR AND MASTER CHIEF

Chief petty officers may qualify for the advanced grades of Senior and Master Chief. These advanced grades provide for substantial increases in pay, together with increased responsibilities and additional prestige. The requirements for advancement to Senior and Master Chief are subject to change but, in general, include a certain length of time in grade, a certain length of time in the naval service, a recommendation by the commanding officer, and a sufficiently high mark on the Navy-wide examination. The final selection for Senior and Master Chief is made by a regularly convened selection board.

The satisfactory completion of the Nonresident Career Course titled *Military Requirements for Senior and Master Chief Petty Officers*, NAVTRA 10115, is required of all personnel advancing to E-8 and E-9.

WARRANT AND COMMISSIONED OFFICER

Figure 1-1 illustrates the path of advancement to Chief Warrant Officer and Limited Duty Officer. The normal path of advancement for TRADEVMEN is to Aviation

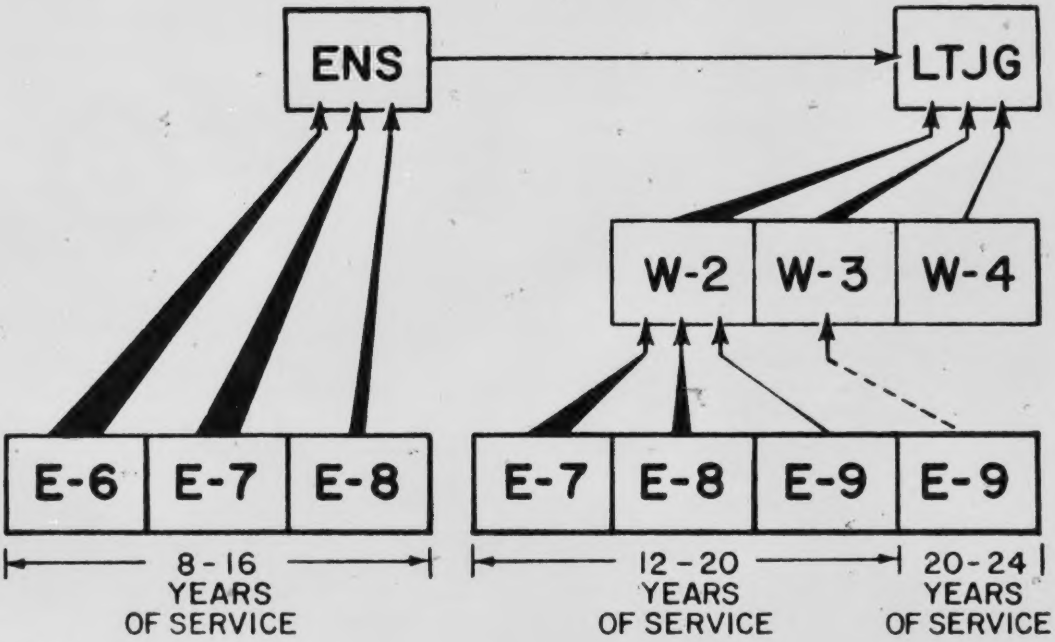

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Figure 1-1.—Path of advancement from enlisted to warrant officer and limited duty officer.

Electronics Technician (738X) and LDO Aviation Electronics (638X). The BUPERS MANUAL, NAVPERS 15791B, provides guidance for submission of application for promotion.

INCREASED RESPONSIBILITIES

When you assumed the duties of a PO3, you began to accept a certain amount of responsibility for the work of others. With each advancement, you accept an increasing responsibility in military matters and in matters relating to the professional work of your rate. When you advance to PO1 or CPO, you will find a noticeable increase in your responsibilities for leadership, supervision, training, working with others, and keeping up with new developments.

As your responsibilities increase, your ability to communicate clearly and effectively must also increase. The simplest and most direct means of communication is a common language. The basic requirement for effeetive communication is therefore a knowledge of your own language. Use correct language in speaking and in writing. Remember that the basic purpose of all communication is understanding. To lead, supervise, and train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

As a PO1 or CPO, you will be regarded as a leader and supervisor. Both officers and enlisted personnel will expect you to translate the general orders given by officers into detailed, practical, on-the-job language that can be understood and followed by relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their jobs correctly. At the same time, you must be able to explain to officers any important problems or needs of enlisted personnel. In all military and professional matters, your responsibilities will extend both upward and downward.

Along with your increased responsibilities, you will also have increased authority. Officers and petty officers have POSITIONAL authority–that is, their authority over others lies in their positions. If your CO is relieved, for example, he no longer has the degree of authority over you that he had while he was your CO, although he still retains the military authority that all seniors have over subordinates. As a PO1, you will have some degree of positional authority; as a CPO, you will have even more. When exercising your authority, remember that it is positional–it is the rate you have, rather than the person you are, that gives you this authority.

A Petty Officer conscientiously and proudly exercises his authority to carry out the responsibilities he is given. He takes a personal interest in the success of both sides of the chain of command. . . .authority and responsibility. For it is true that the Petty Officer who does not seek out and accept responsibility, loses his authority and then the responsibility he thinks he deserves. He must be sure, by his example and by his instruction, that the Petty Officers under him also accept responsibility. In short, he must be the leader his title–Petty Officer–says he is.

For information on the practical application of leadership and supervision, study *Military Requirements for Petty Officer 1 & C*, NAVPERS 10057 (Series).

SOURCES OF INFORMATION

As a PO1 or CPO, you must have an extensive knowledge of the references to consult for accurate, authoritative, up-to-date information on all subjects related to the military and professional requirements for advancement.

Publications mentioned in this chapter are subject to change or revision from time to time–some at regular intervals, others as the need arises. When using any publication that is subject to revision, make sure you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made.

As listed in *Bibliography for Advancement Study*, NAVEDTRA 10052 (Series), the following training manuals and publications are a partial list of those that will be extremely helpful for additional study in preparing for advancement:

1. *Basic Electricity*, NAVPERS 10086 (Series)
2. *Basic Electronics*, NAVPERS 10087 (Series) Vol. I and Vol. II
3. *Tools and Their Uses*, NAVPERS 10085 (Series)
4. *Basic Machines*, NAVPERS 10624 (Series)
5. *Tradevman 3 & 2*, NAVEDTRA 10376 (Series)
6. *Fluid Power*, NAVPERS 16193 (Series)
7. *Manual for Navy Instructors*, NAVEDTRA 107
8. *Digital Computer Basics*, NAVTRA 10088 (Series)

CHAPTER 2

ADMINISTRATION AND SUPPLY

Chief and first class petty officers must recognize the fact that they are an important part of the administration organization. As leading petty officers, their duties entail not only the ability to instruct with, operate, and maintain highly specialized training devices, but they must also be able to perform many administrative duties. These include the preparation of correspondence and reports; using the proper supply procedures for the procurement, issue accountability, and disposition of equipment, parts, and supplies; and supervision of enlisted personnel. All three of the Military Requirements training manuals have pertinent chapters covering these topics.

Their duties also include making recommendations to the training device officer relative to improvement of procedures and practices as well as operational improvement, modification, and alteration of training devices and training aids. Each TD plays an important role in formulating operational procedures, improving maintenance techniques, and overall improvement of the division to better accomplish its assigned mission. He can do this properly only when he has a clear understanding of policies and procedures as well as his place within the organization.

OFFICE ADMINISTRATION AND SUPERVISION

CORRESPONDENCE PROCEDURES

The petty officer in charge of the training device office must be able to prepare and supervise the preparation of official correspondence. Since uniformity in the preparation of correspondence is necessary in the Department of the Navy, all official correspondence must be prepared in accordance with the basic instructions contained in chapter 16, U.S. Navy Regulations; BUPERS Manual, NAVPERS 15791-B (Series), Navy Correspondence Manual, SECNAV Instruction 5216.5 (Series); SECNAV Instruction 5211.3 (Series); and related publications and communications issued by the Chief of Naval Operations. Copies of these publications and instructions are normally found in the personnel office.

FILING PROCEDURES

The Navy filing system is set forth in the Navy Directives System, SECNAV Instruction P5215.1 (Series). This system is used by the entire Navy as the standard subject classification system for the filing of all correspondence, records, reports, and other documents.

It is the responsibility of the petty officer in charge of an office to set up an adequate filing system in accordance with that outlined in the Navy Directives System. The filing system is established in relation to the size and volume of correspondence processed by the particular office concerned. The larger the volume of material which must be filed, the more elaborate the filing system must be to handle the traffic. The main objective of any filing system is to facilitate the finding of any item in the files with the minimum amount of time and effort.

An index should be prepared and placed in the front of each file, listing the contents in the proper classification number order. The standard subject classification numbers (outlined in

SECNAV Instruction P5215.1 (Series)) are used in the Navy for filing all correspondence and directives, and consist of 13 major groups. Small activities may adapt these groups to their needs by preparing file folders for a minimum number of these major subject groups and arranging material within the folders according to classification number assigned. Larger activities may adapt the filing system to their needs by preparing folders not only for the major subject groups but also for the primary and secondary groups.

RECORDS AND REPORTS

In order to have a smooth-running division, it is important to develop an efficient system for keeping records and reports. Reports normally required by training device divisions are listed in table 2-1 and in the Training Equipment Guide, NAVTRADEV P-530-2. Requests to be placed on the standard distribution list for the NAVTRADEV P-530-2 and the other pertinent NAVTRAEQUIPCEN training periodicals should be made through official channels to NAVTRAEQUIPCEN (Code N-423). These items are Cognizance Symbol "I" material and one-time requests should be made by the Supply Officer of the requesting activity. Certain other reports pertaining to device utilization and training personnel are often required by the local command. A tickler file in which all reports are listed according to date required (weekly, monthly, or quarterly) is most helpful. Organizing this file, however, is only the first step in establishing a workable system. The petty officer who is responsible for training device reports must also develop a well-organized method for compiling the information required.

Enlisted Duty Preference Form

The Enlisted Duty Preference Form (NAVPERS 1306/63) is used by enlisted people to make their duty preference known to BUPERS (the detailers), and to assist the detailer in the distribution and rotation of personnel. Instructions for completion of this form are on the form itself and in Chapter 2 of the Enlisted Transfer Manual.

Each person should complete a 1306/63 within 30 days after arrival at a permanent duty station. It must be submitted 10 months prior to PRD or EAOS. Further, it can be submitted any time your duty preferences change.

Training Equipment Change Completion Report, 6ND-NTEC-4720/4

After an activity has modified training equipment in accordance with formal Training Equipment Change Directives issued by the Naval Training Equipment Center, it is imperative that a 4720/4 be sent to NAVTRAEQUIPCEN (Code N-415). This code (department) maintains configuration status accounting for training equipment in the field.

Reporting of Defective or Damaged Training Equipment and Unsatisfactory Material Conditions

Cognizance "20" training equipment received in damaged or otherwise unsatisfactory condition is reported on DD Form 6, and Standard Forms 361 and 363 are used to report and confirm, respectively, discrepancies in shipment. Training equipment casualties which significantly impair the capability to train, are reported according to OPNAVINST 3040.7A and NWIP 10-1 (Series).

Plant Property Accounting, DD Form 1342

The Naval Training Equipment Center is responsible for maintaining a central worldwide inventory record of Cognizance Symbol "20" training equipment in field use which is valued at $1,000.00 or more. This is accomplished through the plant property accounting system. Section 22 of the Training Equipment Guide gives further guidance on the acquisitions, transfers, excesses, and disposals of Cognizance Symbol "20" equipments.

Naval Aviation Maintenance Program (NAMP)

Section 29 of the Training Equipment Guide gives a brief overview of the Naval Aviation

Maintenance Program and the Maintenance and Material Management (3M) System. It also delineates the pertinent instructions applicable to these programs.

Contract Field Service Report, Form 6ND-NTEC-4700/2

When contractor assistance is provided by the Naval Training Equipment Center, the contract service engineer is responsible for filling out the contract field service report covering a weekly period. If on-call contracts are for periods of less than a week, a report shall be submitted for that period. The officer in charge, or the petty officer in charge (OIC/POIC) of the training equipment shall review the report and verify the time distribution and make any applicable remarks.

Utilization and Application Report, Form 6ND-NTEC-10171/4

OPNAVINST 10171.4 (Series) establishes a requirement for custodians to submit a monthly report on the utilization and application of specified Cognizance Symbol "20" training equipment. Detailed instructions for completing this form are provided in NAVTRADEVCEN Data Reporting Instruction, DRI 1-71 and revisions. Copies of DRI 1-71 may be requested from NAVTRAEQUIPCEN (Code N-433), Autovon 791-5200.

All of the reports listed in Table 2-1 are based on instructions that are subject to change. To stay on top of this situation, refer to the Field Service Bulletin, NAVTRADEV P-1550; Training Support Developments, NAVEDTRA P-1300; and the Training Equipment Guide, NAVTRADEV P-530-2.

SUPERVISION OF PERSONNEL

As a Tradevman/First Class or Chief, you may be assigned to a billet in which you may be required to supervise instructors who teach in a classroom, shop, or on some type of synthetic training device. In such a billet, it is your responsibility to ensure that the correct subject matter and skills are being taught. In addition, the presentation must be so effective that the trainees learn the required knowledge and skills well enough to perform the jobs for which they are responsible. Supervision must be constructive and, at the same time, eliminate mediocre teaching.

The Chief of Naval Technical Training has published a manual entitled Procedures for the Planning, Design, Development, and Management of Naval Technical Training Courses, CNTT-A10. Every instructor and supervisor of instructors should read the section on management because it spells out, in detail, the objectives for evaluation. If the individual instructor uses the evaluation form and analyzes his performance in a critical fashion, the possibility for improvement is greatly enhanced.

Training device learning situations involve additional factors not usually present in classroom instruction. Safety and prevention of damage to expensive equipment and training devices are often items of paramount importance. Most training device instruction centers around student practice. Actual instruction procedures in a trainer may vary from one student to another due to individual differences and different levels of experience. For this reason, instructor supervisors must be thoroughly familiar with the technical skills required as well as the best methods to present information to the students.

A continuing program of training is necessary to make the TDs better at their jobs and eligible for advancement. Usually about an hour each day is a reasonable amount of time to set aside for training purposes. Of course, the training should not always be formal; it may be a group discussion on maintenance and operating problems. As a senior TD, you may be given the responsibility of establishing such a program.

An excellent program of training is to have each TD give a series of lessons on the equipment that he operates and maintains. He can point out the characteristics and special troubles that may be peculiar to certain of his equipments. He can also point out short cuts in servicing his equipment. One of the principal objectives is to have each TD know as much as possible about each training device at his

Table 2-1.—Records and Reports

MISCELLANEOUS REPORTS

Enlisted Duty Preference Form, NavPers 1306/63. See Chapter 2 of the Enlisted Transfer Manual.

Training Equipment Change Completion Report, 6ND-NTEC-4720/4. (See paragraph 18-10 and figure 18-3.*) Those activities reporting under 3M utilize OPNAV Form 4790/43, Technical Directive Compliance Form.

Damaged or Improper Shipment, DD Form 6. (See Section XXIII.)*

Discrepancy in Shipment Report (DISREP), Standard Form 361. (See Section XXIII.)*

Discrepancy in Shipment Confirmation, Standard Form 363. (See Section XXIII.)*

Training Equipment Casualty Reports (CASREPTS). OPNAVINST 3040.7A and NWIP 10-1(D) (or superseding issues). (See Section XXIII.)*

Reporting of Unsatisfactory Material/Conditions in training equipment. OPNAVINST 4790.2A (or superseding issue). (See Section XXIII.)*

DOD Property Record, DD Form 1342. (See Section XXII.)*

Report of Excess Training Equipment, by letter or Standard Forms 120 and 120A. (See paragraph 22-31, Section XXII.)*

Activities reporting under 3M submit daily 3M documents to the assigned data processing facility. (See Section XXIX.)*

WEEKLY REPORTS

Contract Field Service Report, Form 6ND-NTEC-4700/2. (If contractor assistance is provided by NAVTRAEQUIPCEN.) (See paragraph 12-20 and figures 12-1 and 12-2.)*

MONTHLY REPORTS

Utilization and Application Report, Form 6ND-NTEC 10171/4. (See paragraph 21-2, Section XXI.)*

* NOTE: Unless otherwise specified, all references to paragraphs, figures, and sections refer to the Training Equipment Guide, NAVTRADEV P-530-2.

activity. This type of program gives the entire division information and some working knowledge of each equipment. One of its benefits is flexibility in assignment of personnel.

Pay particular attention to the training of those who are weak in one or two phases of the work. If a TD lacks skill in a certain type of work, give him a chance to practice it alongside a skilled worker.

Do not use hit-or-miss methods of teaching. Give the individual a definite job to do and check him occasionally on the job. Give him all the help you can. Try to plan his training so that he can acquire the most knowledge and skill in the least amount of time.

When one of your better TDs is working on an unusually difficult job, have some of the others watch the operation. This procedure is invaluable from the standpoint of training, and it also serves as a well-deserved compliment to the one who is doing the work.

In addition to training on specific trainers or equipment, overall training in basic principles should be stressed. Through lecture and discussion and correspondence course study, TDs may be taught the theory and principles of electronic equipment maintenance. Through demonstration, they may be shown the right way to analyze the trouble in electronic equipment and to effect a repair. However, assuming the TD has the proper background information, he learns best by doing. On-the-job training produces the real skill in the repair of equipment. Dexterity, precision, and the feeling for the tools used in repair work come only with experience.

As a senior Tradevman, you are responsible for seeing that the lower-rated petty officers and strikers in your unit receive the proper training to enable them to advance in rating. This requires knowledge, thought, and planning.

SUPPLY PROCEDURES

It is important for every TD1 and TDC to be thoroughly familiar with the procedures used in procuring training devices, repair parts, and routine supplies required for use in their division. As leading petty officers, they may be required to initiate supply action for items required for the division to perform its assigned mission.

It would be beneficial to every E-5/E-6 studying this course to review/study the general supply procedures presented in *Military Requirements for Petty Officer 1 & C*, NAVEDTRA 10057 (Series), and *Military Requirements for Petty Officer 3 & 2*, NAVEDTRA 10056 (Series).

MANAGEMENT RESPONSIBILITY FOR TRAINING EQUIPMENT AND SPARES/REPAIR PARTS

Cognizance Symbol "20" training equipment is under the inventory management of, and is cataloged and distributed by, the Naval Training Equipment Center (NAVTRAEQUIPCEN). The NAVTRAEQUIPCEN is responsible for maintaining a central worldwide inventory of Cognizance Symbol "20" training equipment in field use valued at $1,000 or more. The maintenance of this inventory record is achieved through the plant property accounting system.

Program support for training equipment is assigned to Navy Aviation Supply Office (ASO) Philadelphia, Pennsylvania. ASO is responsible for inventory management of Cognizance Symbol "8N" training equipment spares and selected "1R" items peculiar to training equipment. Cognizance Symbol "8N" training equipment spares are carried in the Appropriation Purchases Account (APA). Cognizance Symbol "1R" training equipment spare parts are carried in the Navy Stock Account (NSA). Training equipment spares/repair parts are assigned SMIC (Supply Management Identification Code) "TD" (Peculiar Spares and Repair Parts in Support of Cognizance Symbol "20" Training Devices).

As the Program Support Inventory Control Point (PSICP) for training devices, ASO arranges for supply support with other inventory managers having cognizance of items, including operational equipment necessary for the operation and maintenance of training systems/equipments/simulators, through the development of Intra-Navy Supply Support Agreements and submission of Supply Support Requests. ASO also arranges for supply support from Integrated Managers having cognizance of items necessary for the operation/maintenance of training equipment.

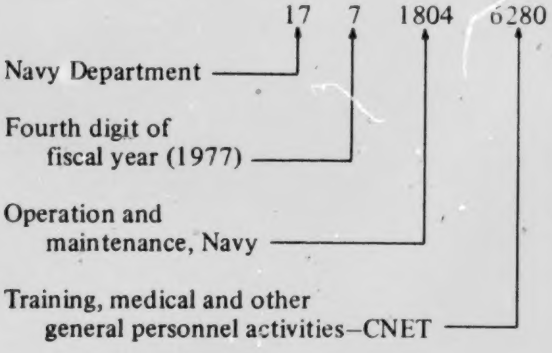
Cognizance Symbol "8N" spares (repairable items) are not provided for obsolete Cognizance Symbol "20" training equipment.

An understanding of Navy appropriations and allotments is helpful for anyone dealing with supply procedures.

An appropriation is an authorization by an act of Congress to spend government funds for specific purposes. Every Navy appropriation is assigned to one of the bureaus or Systems Commands (SYSCOM) of the Navy Department for the purpose of administrative control. They in turn make allocations to the various activities under their management or financial control to carry out their assigned mission.

Appropriations are identified by an appropriation number. For example, 1771804.6280 is the appropriation from which funds are received to maintain training devices in FY 1977. The first two digits of a Navy appropriation number denote the Navy Department, the third digit denotes the last number of the fiscal year, and the fourth, fifth, sixth, and seventh digits denote a particular appropriation. The remaining digits make up the appropriation subhead which further describes the appropriation.

The breakdown of the above appropriation is as follows:


17
7
1804
6280
Navy Department
Fourth digit of fiscal year (1977)
Operation and maintenance, Navy
Training, medical and other general personnel activities–CNET

Funds for Production of Devices

Training devices are produced at the request of, and with specific funds provided by, the cognizant training agency to meet known field requirements within budgetary limitations. Navy activities request development of a new training device or training aid by letter, accompanied by pertinent data containing as much information as possible about the training device or aid and its application. This letter and data must be forwarded to the cognizant training agency via the appropriate chain of command. Informational copies of the letter, along with copies of the data, should be sent to NAVTRAEQUIPCEN and the appropriate Chief of Naval Education and Training Support (CNET Support) field activity.

The five naval training agencies that are able to provide the funds necessary for the production of training devices or training aids are:

1. Chief of Naval Operations (CNO)
2. Chief of Naval Education and Training (CNET)
3. Chief of Naval Reserve (CHNAVRES)
4. Chief of the Bureau of Medicine and Surgery (BUMED)
5. Commandant of the Marine Corps (CMC)

Funds for General Overhead

Each naval station receives funds for general overhead from a resource authorization (operating budget) issued by the bureau or SYSCOM exercising management and financial control over that station. For example, the Naval Air Systems Command issues an operating budget to naval air stations to finance routine maintenance and operation. This operating budget is normally subdivided between the various station departments and covers such items as cleaning gear, office supplies, and materials needed for upkeep of buildings and grounds.

Allocations for Installation, Maintenance, and Modification of Training Devices

For the purpose of supporting its devices at Navy and Marine Corps training activities, CNET Support receives a fund from Chief of Naval Education and Training (CNET) for the support of training devices and technical equipment.

The CNET Support field activities use the funds from this allocation for the logistic support, maintenance, and modification of training devices. (Training characteristic modifications are the responsibility of the cognizant training agency.) This includes local procurement and/or manufacture of repair parts. With the exception of "8N" training device repair parts, all other repair parts assigned NSNs and under the inventory management of the various inventory control points, i.e., Ships Parts Control Center (SPCC), ASO, etc., should be requisitioned locally in accordance with NAVSUP Publication 437. Repair and replenishment of "8N" items are the responsibilities of ASO, and funding is provided by Naval Electronics System Command (NAVELEX) in accordance with an agreement with CNET. The CNET Support field activities provide funds to device custodians for procurement of repair parts and services in support of assigned training devices. CNET Support establishes procedures for administration, accounting, preparation, submission, and justification of funds requested under this program.

CNET Support field activities are authorized to supervise and direct the installation and modification of training devices; in addition, they are authorized to provide specialized maintenance as requested. In the interest of economy and effective financial management, they are also authorized to review and evaluate fund requests from naval activities within their assigned geographic areas.

The commanding officer of the activity to which an allocation is issued is responsible for its proper administration, and accordingly ensures that:

1. Resource authorizations are administered in accordance with statutory and administrative requirements.

2. Funds are used in such a manner as to accomplish the programs, performance of work, or operations for which funds are appropriated and allotted.

As part of its mission, the Naval Training Equipment Center has been delegated certain responsibilities for the configuration management of training devices developed by the Center or placed under its cognizance. In accordance with configuration management policies, NAVTRAEQUIPCEN issues technical directives in the form of Training Equipment Change Directives (TECDs) which provide detailed instructions necessary to perform modification in the field. Materials required for the modifications are usually supplied by NAVTRAEQUIPCEN in kit form.

REQUISITIONING EXISTING TRAINING DEVICES

Any DOD activity may request Cognizance Symbol "20" training devices, in accordance with specific instructions. Government agencies, universities, and other civilian organizations cooperating with the military on training problems may request training devices from the appropriate approval authority.

Except for equipment listed in approved allowances referenced in Section VII of the Training Equipment Guide, NAVTRADEV P-530-2, no blanket authority exists for issue of Cognizance Symbol "20" training equipment.

Existing training devices are not always immediately available to requesting activities. Most devices procured by NAVTRAEQUIPCEN are contract allocated for direct delivery to field user activities. Minor devices having a general application may be stocked in limited quantities by training agencies for subsequent issue to requesting activities, in accordance with the specified approval authority.

Cognizance Symbol "20" training devices are carried in the Appropriation Purchase Account (APA) and are normally issued to naval activities on a nonreimbursable basis.

All requests for Cognizance Symbol "20" training devices are to be made by official letter. These requests are to be sent via (1) appropriate command channels and (2) the appropriate training agency/agencies as listed in the Index to Directory of Naval Training Devices. When the requesting activity receives a copy of the approval endorsement from the cognizant training agency, the requesting activity must provide NAVTRAEQUIPCEN (Code N-432) with a copy of the approval letter request as well as a completed MILSTRIP requisition (NAVSUP PUB 437) for each line item approved.

Activities under cognizance of DCNO (Air) transmit letter requests (for aviation or aviation procured devices) to NAVTRAEQUIPCEN via DCNO (Air). Upon receipt of approval, the requesting activity must submit a completed MILSTRIP requisition to NAVTRAEQUIPCEN (Code N-44) for each line item approved, along with a copy of the approved letter request. NAVTRAEQUIPCEN has approval authority to issue to aviation activities those training devices listed with "Approval Code 1" in Section D of the Index to Directory of Naval Training Devices ("I" Cognizance Order No. 0550-200-0001). For such items, requesting activities must submit a completed MILSTRIP requisition via appropriate command channels to NAVTRAEQUIPCEN (Code N-432). For training devices on the CNO approved allowance list, the current issue of OPNAV Instruction 1551.6 applies.

Request by Ship and Nonaviation Activities

Ships and other nonaviation activities request training devices as outlined in the Training Equipment Guide (NAVTRADEV P-530-2). Again, upon receipt of approval, the requesting activity must submit a completed MILSTRIP requisition to NAVTRAEQUIPCEN for each line item approved, along with a copy of the approved letter request.

Request by Marine Ground Activities

Marine Corps activities other than air submit requests directly to the Commandant of the Marine Corps (OTTS), Washington, D.C.

Request by BUMED Activities

Requests for aerospace/physiological training devices are to be forwarded to NAVTRAEQUIPCEN via the Chief, Bureau of Medicine and Surgery (Code 512) and the Deputy Chief of Naval Operations for Air (OP-596). For devices other than aerospace/physiological, activities under BUMED cognizance forward letter requests to NAVTRAEQUIPCEN via (1) the Chief, Bureau of Medicine and Surgery, and (2) the appropriate approval authority as listed in the Index to Directory of Naval Training Devices. On receipt of approval, the requesting activity must forward to NAVTRAEQUIPCEN (Code N-44) a completed MILSTRIP requisition for each line item approved, along with a copy of the approved letter request.

Request by Army, Air Force, and Coast Guard Activities

Army, Air Force, and Coast Guard activities may procure Cognizance Symbol "20" training devices from the Navy. Procedures for this are found in the Training Equipment Guide (NAVTRADEV P-530-2).

REQUISITIONING TRAINING DEVICE REPAIR PARTS

Policy and procedures for requisitioning, reporting, and handling repairable "8N" training device spares are outlined in the Training Equipment Guide, NAVTRADEV P-530-2. Repairable "8N" training device spares are identified in the current edition of the Master Repairable Items List (MRIL), NAVSUP PUB 4107.

Requirements for non-stock-numbered repair parts should be forwarded to ASO, citing end-use funds. Requisitions should cite the nomenclature, device designator, and serial number of the device for which the replacement item is required; also the manufacturer's name and serial number of the item should be provided. Local procurement is authorized when the repair part has a unit price of $100 or less, or when the training device is not fully operational due to parts failure no matter what the dollar value of the repair part.

All other training device repair parts assigned NSNs should be requisitioned locally in accordance with NAVSUP Publication 437.

The ASO prepares allowance documents to support training devices which have been assigned to ASO for Program Support by NAVTRAEQUIPCEN. Based upon the support code assigned by NAVTRAEQUIPCEN and after completion of provisioning, ASO determines allowance support devices and prepares appropriate training device allowance documents, e.g., Allowance Parts List (APL), or Initial Outfitting List (IOL). The allowance document should be used as a support guide by training device custodians to maintain allowance quantities as required to support training devices for a 90-day period.

INVENTORY AND ACCOUNTABILITY

While NAVTRAEQUIPCEN requires reports on devices valued at $1,000 or more, this requirement does not relieve accountable activities from internal procedures for class 3 plant property accounting for items valued at $200 or more, as required by NAVCOMPT Manual, Volume 3, Chapter 6.

The head of the department is responsible for inventory and accountability of all equipage assigned to his department. He assists the fiscal office in establishment and maintaining plant property records in the following procedures:

1. In obtaining technical descriptions and preparation and submission of property record cards.
2. In estimating costs where they are not otherwise available.
3. In affixing identification plates, etchings, decalcomanias, or inkings.
4. In determining the estimated life of plant property.
5. In conducting physical inventories.
6. In the expeditious closing of job orders or equivalent authorizations.

Tradesmen are normally required to assist in obtaining information for inclusion on the property record cards and in conducting inventories. Plant property is generally inventoried every three years. However, special inventories of specific activities or categories of plant property may be directed when such inventories are considered to be necessary.

A separate Property Record, DD Form 1342, is prepared for each individual equipment item of plant property. The individual property record form for accessories and auxiliary equipment which is attached to or otherwise a part of an equipment item and which is required for its normal operation, is not maintained. However, the description of such accessory and auxiliary equipment is entered on the respective property record form.

The property record form for Cognizance Symbol "20" material is prepared in accordance with procedures outlined in Volume 3 of the Navy Comptroller Manual. Special instructions for plant property reporting of Cognizance Symbol "20" training devices are outlined in NAVTRAEQUIPCEN Instruction 7321.2 (Series) and Training Equipment Guide, NAVTRADEV P-530-2.

When a piece of equipment is to be taken up in the plant account, it is assigned a Navy identification number. This identification number is affixed to the equipment by identification plate, steel die, inking, decalcomania, or some other suitable media so as to furnish future identification of the item.

The completed DD Form 1342 (Plant Property Record) should be expeditiously submitted to NAVTRAEQUIPCEN (Code N-44) immediately subsequent to delivery of a Cognizance Symbol "20" training device valued at $1,000 or more. The identification number (block 3 of DD Form 1342) is established by the initial accountable activity and is permanent for the life of the item. This number must be perpetuated on all plant property records prepared incidental to interactivity transfers and other dispositions.

Results of scheduled physical inventories by user activities will be compared with plant property records of the accountable activity. Cognizance Symbol "20" items (training devices, accessories, and test equipment) valued at $1,000 or more found to be on hand and not in the activity plant property account will be immediately reported to NAVTRAEQUIPCEN (Code N-44) by DD Form 1342.

When Cognizance Symbol "20" items are transferred from one activity to another, appropriate portions of the previously retained DD Form 1342 should be completed and a copy of the form should be forwarded to NTEC. The receiving activity will acknowledge receipt of the item by preparation and submission of a new DD Form 1342 to NTEC. The original plant property record identification number will be perpetuated on the new form.

Prior to transfer of a training device, an inventory should be conducted by the responsible activity to verify the availability of all material required to be transferred with the device.

The identification number assigned to Cognizance Symbol "20" material consists of two elements: the accounting number of the activity or contractor's plant where the identification tag is affixed, and a 6-digit identification number suffix consisting solely of numbers. Numbers need not be assigned consecutively, but precautions should be taken to ensure that the suffix number is not assigned to more than one piece of equipment. The fiscal officer assigns blocks of identification numbers to the various departments. He maintains records and strict control of all Navy identification numbers assigned by him. He maintains records of all Navy identification numbers in this series that are destroyed, mutilated, or for any other reason not used.

Inventory of plant property consists of the physical sighting of all items contained on the property record form. At the time of inventory, any items (of a plant account nature) found on hand and not already on the plant account records are taken up on the records. Action is also initiated at the time of inventory to expend from the records any items found to be worn out, broken, or unsuitable for use.

DISPOSITION OF TRAINING DEVICES AND REPAIR PARTS

For all Cognizance Symbol "20" training devices in excess of the requirements, the following reporting procedures apply:

1. All using activities are requested to report excess training devices to NTEC via appropriate command channels for screening and disposition instructions.

2. Reports should be made by letter or on Standard Forms 120 and 120A. Letter reports are the preferred method.

3. Excess training device reports should include the following information for each training device:

a. Indicate the device designator, stock number, and serial number as taken from the device nameplate.

b. Indicate the "condition code" applicable to the trainer, based upon a thorough inspection of the actual physical condition of the device, not a superficial inspection based on age, obsolescence, or general appearance. (Condition codes and expanded definitions are outlined in NAVTRADEV P-530-2.)

c. Indicate all missing items on an "itemized deficiency list" attached to the letter report or Standard Form 120. The itemized deficiency list must indicate all missing components, accessory items (including maintenance tool kit items), modification kits, and trainer handbooks. Due to the technical characteristics and limited availability of major categories of training devices, the itemized deficiency list is of paramount importance. It enables training commands to determine item useability and NTEC to determine item suitability to fill immediate requirements and/or repairability factors. Itemized deficiency lists are required only for training devices valued at $500 or more.

d. Indicate special factors and other basic information not covered above which, in the judgment of a reporting using activity is considered to be of sufficient value and importance, should be included to assist NTEC to determine item useability.

Training devices declared obsolete in accordance with NAVTRAEQUIPCEN Instruction 4440.7 (Series) may be disposed of subsequent to receipt of written authorization from NTEC. When the obsolete material has been turned over to the property disposal office, a copy of the previously retained DD Form 1342, with blocks 37-41 completed, will be forwarded to NAVTRAEQUIPCEN (Code N-44). Plant property account responsibility and reporting continues until the material is physically disposed of to the property disposal office.

Cognizance Symbol "20" items which cannot be located because of loss, destruction, or other reasons, will be surveyed in accordance with paragraphs 25155-25167, NAVSUP Manual, Volume II. When survey action has been approved, a copy of the previously retained DD Form 1342, with blocks 37-41 completed as appropriate, will be forwarded to NTEC (Code N-44).

Classified training devices authorized for disposal will be processed in accordance with the Department of the Navy Information Security Program Regulation (OPNAVINST 5510.1 Series) and paragraph 02150 of NAVSUP PUB 437.

Excess repair parts which are in all respects ready for reissue, repairable, or of value as scrap should be turned in to supply on DD Form 1348-1 for screening and disposition. Worn, broken, or damaged parts having no value as scrap or as an overhaul item are disposed of locally by the activity.

ADMINISTRATIVE ASSISTANCE

The field services provided by the CNET Support field activities and NTEC include the following:

1. Assistance in utilization of training aids and devices.
2. Field engineering assistance in installation, maintenance, and modification of training devices.
3. Assistance in the administration of Tradevmen.
4. Indoctrination of training officers and training device administrators (and certain enlisted men) in special courses.
5. Furnishing of utilization and maintenance manuals and parts catalogs of devices, as well as other technical and training publications and reports of Center activities and developments.

UTILIZATION ASSISTANCE

The program of utilization assistance is designed particularly to provide assistance in the following four areas:

1. Fitting a device into the training program.
2. Gaining instructor acceptance of the device.
3. Training instructors to use the device most effectively.
4. Overcoming specific teaching limitations of a device.

Any training activity may request assistance in the use of a training device by contacting the appropriate CNET Support field activity.

In many cases, utilization assistance begins with a demonstration of the device by CNET Support field activity personnel to the training personnel of the receiving activity, immediately upon receipt of the device in the field. Since personnel limitations do not permit such an introduction of every device, nor is it always necessary, priorities for this service are determined on the basis of the following factors:

1. Importance of the device to the training program.
2. Critical nature of the training program.
3. Known problems in using the device.
4. Complexity of the training situation.
5. Cost and complexity of the device.
6. Requests from the training activity for a field demonstration.

In many cases, after a device has been in use for a while, CNET Support field activity personnel again visit the field to further clarify the place of the device in the training program. They resolve any problems that may have arisen since the demonstration or introductory visit. The information gained at the second visit to the field is passed on to other users of the device.

FIELD ENGINEERING ASSISTANCE

Field engineering services offered by the Training Equipment Center include device installation, maintenance, modification, repair, and overhaul. These services may be performed by personnel of CNET Support field activities, or by contract field engineers.

The present trend in this area is to use government hired and trained civilian personnel who are capable of rendering this assistance. However, since NTEC presently has maintenance contracts with commercial firms, field engineering assistance is discussed.

Requests for special assistance in installation, maintenance, or modification of a device under the cognizance of the Training Equipment Center are sent to the cognizant CNETS field activity. Services provided by contract field engineers are at no cost to the requesting activity. Requests should state the number and type of devices to be serviced, location of the devices, nature of the problem, date the services are desired, and whether the work is urgent or routine.

In accepting the services of contract field engineers, the activity should make arrangements to obtain the maximum value from the contractor's representative. The activity should provide all possible assistance and facilities as required to aid the representative in the performance of his duties. The OIC/POIC of the trainer signs the engineer's Field Service Report (NTEC 4700/2). This report contains a record of the time expended, description of work performed, troubles encountered, corrective measures taken, information given to military personnel, and any recommendations or other pertinent information. If the work was not completed, the report should contain a statement explaining why it was not completed and when it is expected to be completed.

Some contract field engineers are also available to conduct specialized training courses in the operation and maintenance of certain complex devices at local activities. Requests for specialized training are sent directly to the Center. When instruction for a period longer than two weeks is to be conducted by the contractor's representative, the Center should be notified 60 days in advance of the desired date of the course. The number of local personnel to be trained, and the number of personnel from other activities that can be accommodated, should be stated in the request.

TRAINING EQUIPMENT CHANGE PROGRAM

Devices may require modification/changes for one or more of the following purposes:

1. To improve circuitry or design.
2. To improve ease of operation.
3. To improve simulation of operational equipment.
4. To improve maintenance reliability features.
5. To improve safety of operation.
6. To modernize training devices to conform to changes in operational equipment.
7. To adapt devices to new training requirements.
8. To tie in with other training devices or operational equipment.

Modifications are normally the result of recommendations proposed by the manufacturer, Center personnel, contract engineers, field personnel, and service test reports. Changes in operational equipment may require modification of devices so that device configuration gives the correct simulation.

Requests for modification of a training device are submitted on Form 6ND-NTEC 4720/2. These requests are prepared in accordance with NAVTRAEQUIPCEN Instruction 4720.1, a copy of which is contained in the Training Equipment Guide, NAVTRADEV P-530-2. Modification assistance may be requested from the appropriate CNET Support field activity. After review of a modification request, the Training Equipment Center, by letter of acknowledgement, approves, disapproves, or states further action required before approval is given.

Field activities have no authority to modify a training device except as specified by an applicable NAVTRAEQUIPCEN Training Equipment Change Directive. After an activity has modified a training device in accordance with a formal modification order, it will send a Training Equipment Change Completion Report 6ND-NTEC 4720/4 to the Naval Training Equipment Center.

OVERHAUL PROCEDURES

Facilities for the overhaul and repair of Cognizance Symbol "20" training devices are maintained at locations convenient to naval training activities. Any training device or component of a device may be reconditioned in NAVAIRSYSCOM Naval Rework Facility at the following naval air stations:

NAS, Norfolk, VA
NAS, Pensacola, FL
NAS, San Diego, CA
NAS, Alameda, CA

Basically, the work schedule includes:

1. Planned programs.
2. General rehabilitation of Cognizance Symbol "20" material.

Planned programs consist of work which can be planned or scheduled in advance, including periodic processing based on elapsed time or hours of use, and the processing of equipment which proves unreliable for unpredictable causes. General rehabilitation of Cognizance Symbol "20" material concerns the reconditioning of devices returned to stock because they are in excess of the needs of a training activity.

To provide an orderly movement of devices through the Naval Air Rework Facility, shop schedules are issued quarterly, 90 days in advance of the period in which the work is to be done.

Activities controlling a device needed for a continuous training program often hesitate to report that the device is in need of minor repairs. Such repairs can be greatly expedited by contacting the cognizant CNET Support field activity representative. Most of these field offices have an allotment of hours on the NAVAIRSYSCOMREP schedules which is set aside for the express purpose of making minor repairs to devices. This procedure eliminates much paper work, shipping orders, etc., and hastens accomplishment of minor repairs which might otherwise be neglected. Navy and Marine Corps activities may request overhaul of training devices by letter to the cognizant CNET Support field activity.

Shipping Procedures

All devices requiring repair, overhaul, or reconditioning are to be transferred to the overhaul point designated by the cognizant CNET Support field activity and in accordance with NAVTRAEQUIPCEN MILSTRIP authorization. The devices to be shipped are to be turned over to the supply officer for packing and crating. All packages and crates are to be marked "Cognizance Symbol "20" material" for complete devices, including appropriate stock numbers, device numbers, and nomenclature.

CHAPTER 3

SUPERVISION OF MAINTENANCE AND OPERATIONS

THE MAINTENANCE PROBLEM

Supervision of maintenance and repair of training devices is a major responsibility of senior Tradevmen. Complexity of the maintenance work is determined by the trainer and/or trainers involved. Training aids and demonstrators utilize simple mechanical and electromechanical units in their operation. These simple units can be kept in good working order with minimum personnel and effort, while complex trainers require highly qualified technicians and organized maintenance facilities.

The training devices at a particular station, ship, or training unit vary a great deal from devices at other commands; therefore, this chapter has been written in a general vein so as to include information that will be of value to the Tradevman supervisor no matter what his duty assignment.

PERTINENT MAINTENANCE PUBLICATIONS

In connection with maintenance and repair of training devices, a thorough knowledge of the use of various publications available to TDs will prove helpful. These include:

1. Handbook of Operation and Maintenance
2. Training Device Log, NAVTRADEV P-3229
3. Naval Training Equipment Center Field Service Bulletins

Handbook of Operation and Maintenance

A handbook of this type is prepared for use as an aid in understanding and performing installation, maintenance, and adjustment procedures for each training device. It provides an excellent source of readily available material for each equipment. It is advisable for the Tradevman to spend some spare time in becoming familiar with its contents prior to having to work on the trainer, rather than waiting until the need is at hand. This is especially true of the section on Theory of Operation and the section on Maintenance.

Training Device Log

These records provide valuable information to maintenance personnel by showing a continuous history of the performance and maintenance of a particular training device. When kept in accordance with instructions, the log serves as a valuable reference, aids in maintenance and repair work, and improves the quality and dependability of the training device.

Field Service Bulletins

These publications are issued periodically by the U.S. Naval Training Equipment Center (NTEC) to provide a medium for the exchange of information between field activities. Articles submitted by activities give worthwhile information on improvements in the use, modification, and maintenance of training devices.

MAINTENANCE AID

The NTEC has maintenance contracts with several commercial firms to assist in the maintenance and servicing of various complex training devices. The Navy currently has a programed schedule for replacing these commercial contracts. This is being accomplished by hiring and training civilian personnel who are capable of giving this assistance. Information on requesting assistance in maintenance and further information on the Center's maintenance aid program is contained in chapter 2 of this training manual.

MAINTENANCE AND REPAIR FACILITIES

As a supervisor, a TD1 or TDC is expected to spot operating difficulties in his unit and correct them. He must understand his department, station or ship organization, and the proper channels and lines of authority which are open to him. The higher a petty officer progresses up the organizational chain, the greater the administrative responsibilities.

The job of a supervisor is many sided and has particular importance with respect to the operation of a maintenance and repair facility. A weakness in the performance of any supervisory duty or responsibility reduces the effectiveness of supervision.

The TD supervisor should fully appreciate and understand the responsibility he holds as a member of the organization, and be able to identify each of his duties with respect to the whole–not an easy task in a field as complex and variable as the work of a supervisor. Therefore, only by study and analysis of each part of this job can he expect to prepare himself to execute these many duties effectively.

Some administrative personnel have made long lists of the responsibilities of supervisors. A close examination of such lists might disclose to each man the points of difference as well as the points of agreement. Many of the differences are of minor importance, but others represent real differences in responsibilities. The following list, although suggestive rather than authoritative, includes the duties and responsibilities which are common to most TD supervisors:

1. Placing qualified personnel on the job at the right time.
2. Preventing conditions that might cause accidents.
3. Utilizing tools and materials as economically as possible.
4. Keeping personnel satisfied and happy on the job.
5. Adjusting grievances.
6. Maintaining discipline.
7. Keeping records and making reports.
8. Maintaining quality and quanity of repair work.
9. Planning and scheduling repair work.
10. Training personnel.
11. Requisitioning tools, equipment, and materials.
12. Inspecting and maintaining tools and equipment.
13. Giving orders and directions.
14. Cooperating with others.
15. Checking and inspecting repaired equipment and replacement parts.
16. Settling differences between personnel.
17. Promoting teamwork.

From the extent of the above list, it is obvious that the job of a supervisor covers a broad field, and that a detailed study of such a job is not practicable in this limited space. These items are quite general in nature; therefore, it is necessary for each supervisor to carry out a detailed study of his own specific duties and responsibilities.

There are a number of good training manuals that teach the principles of leadership. One example is *Human Behavior and Leadership*, NAVEDTRA 10058 (Series).

The TD in charge should take advantage of every opportunity to provide his people specific information about their jobs. If, for example, a TD is making periodic inspections, his interest will be greatly stimulated by his supervisor telling him why the inspections are necessary and explaining the importance of the job with respect to the entire project. The type of supervisor who says, "Never mind why; just do as you are told," is rapidly being replaced by the supervisor who recognizes the importance of each individual knowing why he is performing a job.

A supervisor should utilize all possible interest factors. They should study each of their people and use information gained to obtain the best results according to individual characteristics. Their ability to interest their people in their work is important to them, as it has a part in determining their success or failure as a supervisor. The supervisors proficiency in rating depends in part on the quality and quantity of work their people produce, which in turn reflects the interest and morale of the people in their work.

SHOP LAYOUT

The physical dimensions of a repair shop vary throughout the Navy. The space requirements will vary with each activity. The result is generally that the available spaces must be used as efficiently as possible.

The leading petty officer should plan the layout of the shop in such a manner that a maximum number of repair jobs can be conducted at the same time. An area should be provided for electronic repairs. This includes standard electronic benches which provide shelves for test equipment and electric power outlets for the equipment. Clearance should be maintained around this work area to provide safety for the maintenance personnel. (See Safety Precautions for Shore Activities, NAVMAT P-5100.) Rubber mats should be laid on the floor wherever electrical and electronic repairs are to be conducted. Lighting for this area, and the whole shop, should be carefully planned to provide maximum illumination.

A bench area should provide space for disassembling and overhauling small mechanical components. The layout of this bench should allow ease of cleaning of the disassembled equipment or components as well as the bench space. Bench equipment, such as a vise, grinder, or drill press, should be permanently mounted on the bench.

Floor space adjacent to the bench should be provided for the repair of equipments too large to be placed on the bench. Also, a doorway large enough for this equipment should adjoin the work area.

Space should also be provided for maintaining records, logbooks, etc. Clear and well-kept records and reports are good indications of well-planned supervision.

CARE OF TOOLS AND EQUIPMENT

Orderliness is a prime essential of good shop operation. There must be a place for every tool, and each tool must be returned to its place after use. By seeing that this practice is observed, the people under your supervision will be able to find any tool at any time, without wasted effort.

In a shop, cleanliness, like orderliness, is a very important factor. If tools are to serve their purpose most satisfactorily, they should be cleaned after they have been used. Tools in localities of high humidity should be wiped with a cloth containing a light oil. In applying oil, care must be taken to see that it does not get on the wooden handles of saws, screwdrivers, and other tools.

An untidy shop is an unsafe shop. For this reason, it is important that tools, machinery, workbenches, and floorspaces be kept clean. Piles of greasy and oily rags are fire hazards. Spilled oil on benches and decks may cause serious injury. All equipment should be checked to make sure that guards have been installed and retained on all moving parts of equipment.

Operating instructions and safety precautions should be posted at each machine. It is good engineering practice to comply with all the requirements listed in the operating instructions and safety precautions.

STOWAGE AND INVENTORY OF TOOLS AND EQUIPMENT

The number, character, and location of supply stowage spaces depend upon the particular room or building where the training device shop is located. If the supplies for the shop are bulky and heavy, the room should be accessible to a delivery platform as well as easily accessible to the shop which it serves.

The method of distributing tools and supplies is also dependent upon the particular shop. A plan of distribution of supplies should be developed as a part of shop planning.

Stowage racks and bins within a stowage space are so dependent upon the materials to be handled that few general recommendations apply. It is necessary that maximum sizes and quantities of materials be estimated in planning the size and location of the space. In order to facilitate inventories and reordering, supplies should be stowed in sight in open bins, racks, and shelves, wherever such arrangements can be made, rather than in closed cabinets and boxes.

SHOP HOUSEKEEPING

A quick survey for cleanliness, neat tool and stock stowage, and the condition of equipment will tell whether the workshop is well organized and managed. A clean, well-organized shop normally reflects high quality maintenance.

Material and supplies must be stowed in a convenient, secure, and orderly place. Use cabinets, shelves, bins, and racks arranged in the shop to give the greatest possible amount of free working space.

If shop space permits and sufficient tools are available, each rated person should have his own stowage drawer and toolbox in which he can keep the tools that are ordinarily used. This method of stowage not only provides better care and cleanliness of handtools but increases production.

If space permits, one corner of the shop may be blocked off for use as a toolroom. A striker should be made responsible for keeping the tools in order and issuing them as required. This toolroom job should be rotated among the strikers to give each person an opportunity to learn the names and uses of all the tools. You should encourage each striker to complete the nonresident career course based on the rate training manual, *Tools and Their Uses*, NAVTRA 10085 (Series).

Tool stowage is an important item in the shop. Lockers, racks, drawers, cabinets, and boxes are used for stowing tools. The place selected depends largely on the use of the tool, the frequency of its use, its size and shape, and its value.

One of the jobs of the TD in charge of a shop is to maintain a system of accountability for valuable tools and equipment. He should see that custody cards are made out for tools and equipment, including such items as portable power tools, gages, micrometers, and special sets of handtools. Tools which are of a highly "pilferable" nature should be accounted for at regular intervals.

Tools and equipment used outside the shop should be made up in kits and stowed in convenient toolboxes. Tools used in the shop may be marked with a distinctive color for identification. If so marked, they are not easily mixed with tools that belong to other shops.

SAFETY PRECAUTIONS

The development of safety consciousness is an important part of every supervisor's responsibility. Safety in shops cannot be taught in a lesson or even in a series of lessons. Safety is actually a combination of attitudes and proper work habits which can best be developed by repeated emphasis of safety practices at all times and focusing attention on the prevention of accidents.

Safety instruction should emphasize both the physical elements (those inherent in a machine or in the operation of a machine) and the human elements (ignorance, carelessness, fatigue, etc.). Every operation should call attention to the safety factors involved. The supervisor should be alert at all times for evidences of carelessness and call them to the attention of the personnel immediately.

Accidents do not just happen–they are caused. Many accidents can be prevented by discovering and eliminating the causes. All analyses of operations that will be carried out in the shop should include analyses of safety factors. By investigating and analyzing accidents, you will help prevent their recurrence.

TRAINING MAINTENANCE PERSONNEL

If the TD in charge of a shop has a well-planned program for introducing new personnel to the work in the shop, he has taken a most constructive step toward building shop morale. One of the best stimulants for the development of high morale among new personnel is to have them realize that the supervisor understands their feeling of strangeness and is aware of their desire to make good. There is often a gap between the point at which a new individual is assigned and the time at which he has developed into a satisfied worker. Proper introduction to the new work bridges this gap, turning an ill-at-ease person into a confident and interested worker. The supervisor is responsible for acquainting him with the working area and for developing him into a satisfied, well-balanced worker in his unit. During the early employment period, many of the things told to a new person "go in one ear and out the other" because his interest is centered on getting to the job, rather than on what he is told about the job.

The supervisor will find it a profitable procedure to review with each new TD such matters as duties, drills, liberty and leave regulations, and similar policies. This initial indoctrination need not take long, but the senior TD should be sincerely interested in becoming acquainted with the individual and providing essential information about the department and work. The initial contact should be made primarily to win the new TD's confidence. The supervisor may later turn the TD over to a qualified petty officer who is capable of completing the introduction process and the early training necessary. In most cases, considerable information can be given by an experienced petty officer selected by the senior TD.

In carrying out this responsibility, the TD1/TDC must do a certain amount of planning if the instructions necessary for the proper indoctrination of the new worker are to be accomplished effectively.

At this point, it may be well to indicate one fundamental difference between the work of a supervisor and that of his people. The people work with machines and material, while the supervisor works through people to produce the desired results with the machines and material. The machines may be operating perfectly and the materials may be of the best quality, but unless the personnel who handle them are properly instructed, adjusted to their work, and cognizant of their place in the organization and of the policies of the department, they will not be satisfied workers.

The senior TD is responsible for developing high morale in his shop. The first step is attained by properly indoctrinating each TD at the time they report aboard. The three general areas of indoctrination are:

1. Those dealing with facts, such as the rules and regulations.

2. Those dealing with an individual's attitudes or feelings, his confidence in the organization, pride in the job, and respect for his fellow workers.

3. Those dealing with skills, safe working habits, and quality of work.

To aid in developing TDs for greater responsibilities is an all hands job. Each person not only must be receptive to that which helps to develop himself, but must also help to develop those who assist him. However, the senior TD in charge has the direct responsibility to see that all subordinate personnel understand their work and its relation to the function of the shop.

Additional information which will aid in the training of maintenance personnel is contained in *Military Requirements for Petty Officers 1 & C*, NAVPERS 10057-C. CNETS Field Activity field service engineers may be used to provide specialized on-the-job training for maintenance personnel. Arrangements for such assistance is normally made through the cognizant Field Activity.

MAINTENANCE AND REPAIR

The advanced Tradevman has already developed certain techniques in troubleshooting training devices. However, this portion of the chapter summarizes in a general way certain techniques or methods that may be applied to almost any type of electronic equipment. A detailed technique for troubleshooting digital systems is given in chapter 9 of this manual.

The necessity for a thorough knowledge of the fundamentals of electricity and electronics cannot be emphasized too strongly in performing any type of logical and systematic troubleshooting. The entire concept of effect-to-cause reasoning is based on a thorough knowledge of these fundamentals.

Because of the complexity of most naval electronic circuits, a malfunction can be the result of the failure of a small component or a small change of value of a critical characteristic of a component. The first situation requires the replacement of a part; the second situation may frequently be corrected by adjustments. It is this complexity that requires the development of a practical and logical approach whereby the possible simple causes are established or eliminated first. The difficult ones can then be pinpointed quickly. If necessary, replacements should be made prior to adjustments, otherwise the difficulty in isolating a faulty component may be greatly increased.

In all failures of electronic equipment, telltale evidence exists that will reveal the system, major unit, or component in which the trouble exists. Therefore, the first step in troubleshooting should be localization. This localization process must be broken down into three phases–system localization, unit localization, and component localization. System localization involves localization of the trouble to a system primarily by operational responses and, in the case of operational trainers, by instrument indications. Unit localization involves localization of the trouble to a unit, primarily by using a system data flow chart, block diagram, or signal flow chart. Component localization involves localization of the trouble to the defective component within the unit by voltage tests, signal tracing, and resistance tests.

System troubleshooting, or localization of a trouble to a particular system, is a logical application of equipment familiarization and a practical utilization of symptom indication. In operational trainers the task of locating the trouble may be simplified by operational checks or instrument indications. Instrument indications should give sufficient information to enable the TD to localize the trouble to one of the major systems.

Unit troubleshooting requires the use of block diagrams, signal flow charts, and the system data flow which are usually found in the maintenance handbook. The use of an oscilloscope permits comparison of waveforms in isolating a trouble to a faulty unit.

Component troubleshooting is the localization of the trouble to a particular component. The schematic diagram, wiring diagram troubleshooting charts, tube, transistor, or location diagrams, and other maintenance information, which are found in the equipment instruction book, assist the TD in localizing the faulty component. Obvious troubles, such as blown fuses, loose connections, or arcing, can usually be determined by visual inspection and the presence of unusual odors.

Signal tracing through the unit to a faulty stage is the most often used procedure. The size of the unit would determine whether signal tracing by stages or isolating the unit into subunits by checking input and output waveforms would be the best procedure to follow. Once the stage is determined, voltage and resistance checks should be made. When incorrect voltages are found, resistance checks may be made to establish the cause. Voltage and resistance indications are also included in the equipment instruction book.

If the TD is observant and employs analytical and logical effect-to-cause reasoning, the troubleshooting procedure can be shortened considerably. Often the faulty unit, or even the component, may be singled out before removing a single panel or inspecting a single computer.

PREVENTIVE MAINTENANCE

Most training devices comprise both complex electronic units and delicate mechanical equipment. Satisfactory operation therefore requires employment of the best standard maintenance procedures for both types of equipment in order to maintain the trainers in the best operating condition. It is necessary to adopt a systematic procedure for both daily and periodic inspection and servicing with the objective of anticipating and forestalling trouble, making immediate repairs, and in general assuring uninterrupted and smooth functioning of all units of the trainers.

Failure in the equipment during continued use may range from sudden breakdown, where the seat of the trouble is at once clear, to general overall wear and deterioration of the various components over a long period of time. Particularly, guard against general overall deterioration by conducting complete inspections and tests, both daily and at periodic intervals.

In the Training Device Log, NAVTRADEV P-3229, record all failures, alterations, and observations concerning the equipment, thus permitting a valuable systematic use of accumulated operational and maintenance experience.

Periodic Inspections

The main operating units of the trainer must be checked each day. It is desirable to make daily visual and operational inspections to anticipate functional difficulties. The Handbook of Operation and Maintenance/MRC cards gives detailed information on how the checks and inspections should be conducted.

The daily inspection should include both a visual and an operational check. The trainer should be checked visually for loose leads, improper connections, leaking capacitors, etc., prior to applying power to the equipment. The observations of the operational function of a trainer and the indications received will aid in establishing whether the trainer is functioning properly. An improper indication will aid in localizing the trouble to a component assembly or subassembly.

The daily inspection will often reveal discrepancies that may be corrected at that time with minimum amounts of labor and parts. Such discrepancies, if left uncorrected, might result in a major maintenance problem.

The complete system should be checked at regular intervals. Experience will determine how often these checks are necessary. However, it is better to check too often than to permit breakdown to occur. The Handbook of Operation and Maintenance Instructions will provide information on how periodic inspections should be carried out. To ensure that the equipment is maintained in its best condition and at peak performance, the following general procedures should be followed:

1. Always keep equipment clean.

2. Measure the outputs of all power supplies at frequent intervals. Make any necessary adjustments.

3. Make visual checks of functioning of all mechanical units, such as motors, gears, differentials, bearings, etc., that are visible when equipment is in operation.

4. Become familiar with normal sounds of relays and rotating parts; characteristic appearance of indicators, instruments, and dials; and temperatures of transformers, motors, and resistor assemblies while the equipment is in operation.

5. Always tighten all holddown screws on cable mounting lugs and terminal boards whenever maintenance is performed on the trainer. However, it is not advisable to tighten setscrews on gears, shaft couplings, and other rotating components as a routine procedure while performing other maintenance. Such tightening could introduce backlash, disturb critical adjustments, or strip the screw threads.

CORRECTIVE MAINTENANCE

In maintaining and servicing operational trainers, it is of primary importance to look for simple malfunctions. The method suggested below offers a good procedure for recognition and location of trouble:

1. Observation of controls and instruments.
    a. Do all controls have proper loading for the operational condition existing?
    b. Do all instruments register the appropriate indications?
    c. Do all instruments follow properly when operational conditions change?

2. Analysis for possible cause.
    a. If trouble exists, is it confined to a single system?

- b. Is it electrical or mechanical in nature?
- c. If electrical, can it be caused by
  - (1) a faulty power supply?
  - (2) a bad tube, transistor?
  - (3) an open circuit?
  - (4) a short circuit?
  - (5) an open potentiometer?
- d. If the trouble is mechanical, can it be caused by
  - (1) a loose cam?
  - (2) a broken microswitch?
  - (3) a jammed shaft?
  - (4) fouled gear teeth?

3. Study of schematic drawings.
   - a. Before using tools or test instruments, study the system and chassis schematics and analyze the problem as follows:
     - (1) Break the trouble down into causes which could originate in a certain system or systems.
     - (2) Localize the trouble to an area of the trainer.
     - (3) Determine, if possible, which chassis is originating the trouble.

4. Preliminary testing.
   - a. After the system or chassis causing the trouble has been tentatively determined, use the necessary tools and test instruments to determine which components are causing the trouble and adjust or replace them as required.
   - b. It is rarely necessary to realign the entire trainer. It may be assumed that since the trainer was operating properly prior to the occurrence of the trouble, all potentiometers, cams, switches, etc., were then in proper alignment. Minor adjustments are normally made as required during regular inspection and maintenance periods. Therefore, an adjustment must never be undertaken until it first has been definitely ascertained that the adjustment is necessary. In many cases, what appears to be misalignment will prove to be a defective transistor, potentiometer, or some similar fault.
   - c. In no case should any adjustment be attempted until the equipment has been turned on for sufficient time to assure that all components have arrived at a stable operating temperature condition. Adjustments made before the equipment has had time to warm up will ordinarily be faulty.
   - d. Testing and alignment cannot be performed with inaccurate or inferior test equipment and instruments. The instruction handbook for the trainer will itemize the approved test equipment.

Not until the above checks are made should additional tests be undertaken. The troubleshooting charts in the maintenance handbooks give typical troubles and their causes, but for obvious reasons they are not intended as complete guides to troubleshooting.

By maintaining accurate maintenance logs you can determine if troubles occurring in the trainer are caused from particular parts or circuits. A particular component may continually break down because of unusually high voltage, or methods used to operate the trainer. The records of continuing trouble will show a trend of future breakdowns. A study of the operation of the circuitry may indicate that a change in operating procedures is necessary, or a modification to the trainer should be made.

The procedures set forth in the latest edition of NAVTRAEQUIPCEN Instruction 4720.1 are to be followed when you accomplish a modification change or when an activity desires assistance in developing a modification.

(See the Training Equipment Guide, NAVTRADEV P-530-2.)

SUPERVISING REPAIR WORK

One of the most important duties of a senior Tradevman is that of supervising repair work. He instructs personnel concerning the different repair jobs which must be done. He checks on the progress of the work, and gives additional advice or instructions when necessary. He should also check the job to see that it has been performed and completed properly and in accordance with his instructions.

After the senior TD in charge has obtained complete information on a new job and has decided what repaired or replacements are necessary, he must then decide who is to do the job. In order to make this decision, the supervisor must know what experience his people have had with different types of repair work, and what skills they have in operating test equipment and in using tools.

When the workload is light and time is available, the senior TD can assign new jobs to relatively inexperienced personnel in order to give them training and experience. However, if a job must be performed in a short time, the chief will generally assign the job to one of the more experienced TDs. In routine assignments, the more complicated and difficult repair work is given to the higher rated people and the less difficult jobs are given to the lower rated people. The assignment of a new job also depends a great deal upon the availability of tools, test equipment, and personnel.

STARTING THE JOB

The one who is going to do the repair job must be given detailed information on how the job is to be performed. The senior TD should be careful to see that the person fully understands what he is going to do, so as to prevent any mistakes due to misunderstanding of instructions. The amount of instruction depends upon the knowledge and experience of the person concerned. If he is experienced, it may only be necessary to tell him what repairs must be accomplished. Inexperienced people will need additional instructions on what test equipment to use, and the proper procedure to follow. They should understand that they are free to ask any questions in case they are in doubt about any details in doing their assigned work. People will ask questions when it is to their advantage to do so.

In addition to giving instructions on how a job should be accomplished, it is also advisable to give information concerning the importance of the job, the origin of the job, and the part that each person will play in accomplishing the complete repair job. In general, maintenance people are interested in why a job is necessary, and how it is to be accomplished, and will usually turn out better work when they have a clear picture of the total job.

CHECKING PROGRESS OF WORK

The assignment of work is only the first step in processing a job. The TD who is in charge must know his people. He should have a fairly good idea of each person's skill and ability, as well as his knowledge regarding the operation of equipment and accomplishing repair work.

The best way in which the TD supervisor can obtain this knowledge is to make frequent inspections and check the progress of work being performed. In that way, he will have a good idea as to which jobs, or which personnel, will require the most supervising.

When checking on the progress of work, the senior TD should be sure that the technicians are observing proper safety precautions in regard to themselves and the equipment they are operating. In addition, the supervisor should see that each individual is using the proper tools, and note the quality of work being performed.

In case of any doubt, the supervisor should check to see that the technicians understand his instructions properly and are doing the work correctly. If necessary, the chief should provide additional instructions to give a better understanding of the job, or to improve workmanship. By frequently talking to the crew and answering their questions, the supervisor can prevent work and material from being wasted, as could be the case if he were not available to give the correct details. The supervisor who has interest and confidence in his people and their work will find that they have confidence in him as a good supervisor.

Complications may develop on some repairs which may require additional planning and revised repair procedures. By observing the progress of the various jobs, and whether any are ahead or behind the planned schedule, the supervisor will be able to change the schedule in order to prevent "bottlenecks."

CHECKING ON COMPLETED JOBS

When a job has been completed, the supervisor should inspect and approve the work. Inspection is necessary to ensure that the repair job or the replacement parts will be satisfactory. Inspection of repaired equipment and replacement parts may be accomplished either visually or by means of measuring instruments. In addition, tests are performed to check the condition of repaired equipment.

The senior PO is responsible for determining whether the repair job, including replacement parts, meets the following standards:

1. Have the repaired parts been correctly installed in accordance with instructions?
2. Is the repaired item or replacement part free from defects in material and workmanship?
3. Have all parts or accessories to the repaired equipment been replaced or reinstalled correctly?
4. Has the proper replacement part been used in making repairs?
5. Has the part or item been properly checked and deemed ready for service?

The above are some of the things a chief/first class must consider before the job is completed and the equipment ready to be used. No one should allow repair work to be considered complete until the supervisor, the TD technician, and the operator of the equipment are satisfied.

INSTALLATION OF TRAINING DEVICES

In order to have the device available for utilization as soon after its arrival as possible, and to ensure optimum maintenance and performance, certain preparations should be made as soon as delivery of a device is anticipated. Guidance for advance planning of installation is provided in the Training Equipment Guide, NAVTRADEV P-530-2. If further assistance in planning is required, the cognizant CNETS Field Activity should be contacted.

Space and power requirements for the device should be ascertained in advance of delivery. The necessary arrangements for installation of the device should be made. This may include building modifications, additional electrical power and power equipment, and any other pertinent equipment or supplies. If power requirements are unusual, or if the device or training system is large, it may be necessary to obtain the assistance of the local public works department. These requirements are usually stated in the publications pertaining to the device, or they may be obtained from the appropriate CNETS field activity.

Personnel requirements for installation and maintenance of the device should be anticipated prior to its arrival. If additional TDs are required, an increase in the station personnel allowance must be made.

If a new device is of such complexity that NTEC considers factory training of Tradevmen to be necessary, then the NTEC will automatically make arrangements for this training. Key personnel from the receiving activities attend the course. The course is usually conducted in advance of shipping the device to allow planning details to be completed.

Specialized technical assistance is often necessary for the installation and initial maintenance period of complex devices. NTEC normally provides this assistance under the terms of the contract with the manufacturer.

Any special tools, which may be required for device maintenance, are usually furnished as device accessories. Requirements for repair parts should be anticipated and action taken as soon as receipt of the new device is made known.

Early planning for the device's arrival also includes the provisions for funding the installation. Allotments are provided for this program, and requests for funds are made in accordance with NTEC Instruction 7303.1 (through current change).

After the device arrives, the O-in-C/CPO in charge of the installation should see that adequate precautions are taken during the installation, both as to safety of personnel and care of the device. If a field service engineer or contract engineer is assigned, the O-in-C/CPO in charge should see that the necessary manpower and facilities are available.

Evaluation of the device is conducted after all adjustments have been accomplished and a predetermined operating time has elapsed. This evaluation is accomplished with or without the assistance of NTEC. From the results of this evaluation, the cognizant training agency will be advised of the feasibility of further procurements and possible modifications.

INSTRUCTIONAL USE OF TRAINING DEVICES

In the utilization of training devices, considerable emphasis is often placed upon the number of hours of training time secured. While it is important that a trainer be used as many hours per day as possible, quantity without quality will probably result in a comparatively small increase in student proficiency. The devices alone do not train people; a well-planned and well-managed program is necessary.

It is essential that a device be used at its full training potential. A poor training program or negligence in administering a good program may have adverse effects on the student's performance in the task or mission trained for. Poorly devised and badly administered training programs can be dangerous.

It is an urgent and time-consuming administrative responsibility to secure and maintain a smoothly functioning program which adequately trains students in those areas which are required for the safe and efficient performance of their missions. The development and administration of an effective program is not an easy task, nor is it something that can be done and then forgotten. Once a program is put into operation, it is continually necessary to locate deficiencies and to correct malpractices. Responsible authorities cannot blithely assume that any training program is being conducted in an effective manner. Ineffective and dangerous practices may not be apparent to the casual observer; therefore, a system of quality control must be devised for identifying these practices.

REQUIREMENTS FOR QUALITY CONTROL

Training device utilization data has brought to the forefront four requirements which appear critical for controlling the quality of training. These requirements are discussed in the following paragraphs. While these four factors apply primarily to a Training Officer, it is to the advantage of the supervisor of operators (the TDs) to know how or what may adversely affect the optimum use of the simulators.

Adherence to the Training Program

Once a training program has been developed, that program should be followed until changed for good and sufficient reasons. When individual instructors deviate from a prescribed program, they often detract from the effectiveness of training. Even small deviations are often harmful because they seem to breed further alterations, and the end result is frequently a chaotic program in which no one knows what type of training, if any, the average student is receiving. Once a training program is established, provisions should be made to ensure that the training program is carried out as it was planned.

Validity of Information

Every effort should be made to ensure that instructors are giving students the correct information on each procedure taught during a course. The teaching of incorrect procedures must be identified as soon as possible to protect the student.

Frequently these incorrect, and possibly dangerous, procedures are hard to detect. They usually enter the program because of insufficient information regarding the procedure or because of unauthorized deviations from the training program. Constant research is necessary to obtain accurate and definite information on procedures used in the real-world equipment. To this end, operating personnel must actively seek and secure the support of student and training officers.

Maintenance of Equipment

Irregular trainer malfunctions will occur which can have extremely undesirable training consequences. If training is given when malfunctions are present, the possibility exists that the unorthodox procedures required to bypass trainer malfunctions will carry over to the equipment being simulated. This is especially likely when inexperienced students are being trained. If malfunctions are not corrected within a reasonable period of time, training personnel may give up and begin to "live with" the deficiencies. When the supervisor of operators discovers malfunctions that result in the teaching of procedures which do not apply to the actual equipment being simulated, they should take steps immediately to ensure the correction of these malfunctions.

Scheduling of Students

Improper scheduling can have serious effects on student and instructor morale as well as reduce the effectiveness of training. The primary requirements for proper scheduling are:

1. Each student must receive all the training time that has been allocated to him.

2. Each student should meet the proficiency requirements specified for the particular course to which he is assigned.

3. In the case of crew trainers, crew integrity should be maintained for training, if permanent crews are used in the aircraft, ship, or submarine.

4. Each student should be allowed to complete the prescribed course without unnecessary interruptions.

5. A student who has recently completed a course should not be sent back for more training just to "fill quotas."

OBTAINING INFORMATION FOR USE IN IMPROVING TRAINING QUALITY

This section suggests a number of procedures for securing information which the supervisor of operators can use to assist the Training Officer in his efforts to correct deficiencies in training programs. If this type of information is not available, it will be very difficult to make worthwhile improvements, since real deficiencies will probably remain undetected. Methods for correcting the deficiencies are discussed later.

Monitoring Training Sessions

Frequent monitoring of training sessions, briefings, critiques, and other instructional sessions by supervisory personnel are effective ways to obtain information regarding the degree to which operators/instructors adhere to the prescribed program, and to ensure accuracy in the information given to students by instructors.

Supervisory personnel can attend training sessions and look for deficiencies in the conduct of the program. These deficiencies should be recorded as soon and as specifically as possible. General impressions should be avoided, since suggestions based on such impressions will be of little help to the instructor/operator in improving his techniques. It is important to remember that the true situation may not be easily observed by a supervisor. Most operators/instructors are not at their best when being observed, and some will consciously alter their methods when an observer is present.

In some cases, it may be possible to make a tape recording of the training session. Much can be learned in this way, and instructors/operators seldom resent this type of monitoring as long as they have been informed that it will be periodically done.

Analyzing Student Performance Checks

Performance checks can serve as sources of unbiased information on some aspects of training. These records of each student's performance are filled out by the instructors during the training session. Analyses of information obtained from the form employed in administering such checks have proved useful to supervisory personnel in improving the quality of training.

The following are some examples of the types of information which can be obtained from performance-check analyses:

1. Since observations recorded on the performance checks serve as the basis for corrective instructions during the critique, a key function of the instructor is to recognize and record the student's errors. If the observations are made completely and correctly, the instructor can inform the students of their faulty procedures and suggest corrective actions. An analysis of the errors recorded by an instructor can give an indication of his teaching ability by providing such information as the average number of errors he records for each of the normal and emergency procedures included in the training period. If an instructor consistently observes few or no faults actually present in procedures, or neglects certain procedures, the soundness of instruction during the critique is questionable and student errors are likely to be repeated.

2. "Command decisions" made by the students regarding procedures or equipment breakdowns may make it necessary for the instructor to deviate from the prepared training outline by eliminating one or more of the scheduled procedures. However, it is possible that a poor instructor will eliminate an unjustifiably large number of procedures from the training. Such a practice on the part of a poor instructor can seriously reduce the effectiveness of training, since a student may not have a chance to practice all the procedures that have been carefully selected for inclusion in the course. The number of procedures completely omitted from the program by each instructor can be obtained by reviewing the performance checks which he has filled out.

3. Some instructors tend to make their training periods shorter than required by the curriculum. This practice deprives the students of trainer time that has been allocated to them and results in reduced trainer utilization. It also indicates that the instructor is eliminating certain procedures. The length of each training period, as reported on the performance checks, can be used to obtain the average length of the periods conducted by each instructor.

4. Within certain commands, crew integrity is a requirement for effective utilization of multiplace trainers. Whenever possible, crews who are regularly working together should report for trainer practice together. Crew substitutions after a course has started can be harmful and should be approved only under exceptional circumstances. Information regarding crew integrity can be obtained from the form used with performance checks.

Collecting Opinions and Suggestions From Students

The opinions and suggestions of students have proved to be valuable sources of information for improving programs. This information can be obtained by having the students fill out a questionnaire consisting of a number of well-designed items, or by having supervisory personnel interview the students after they complete training. Of these two methods, the questionnaire has some advantages since it will give a record of a large number of student responses which can be tabulated for report purposes, and it requires less of the supervisor's time. However, the interview will result in more detailed information on student opinions and suggestions. In practice, it is probably best to use a combination of the two methods. The questionnaire can be used with all of the students to obtain an overall appraisal of the program; whereas, the interview can be used occasionally to obtain detailed information and suggestions pertaining to persistent problem areas.

General topics upon which student opinion and suggestions can be obtained are:

1. Differences between the trainer and the actual equipment which could possibly have an adverse effect on the student's subsequent performance in the vehicle.

2. Type, amount, and value of instruction given during briefings, critiques, training periods, and lectures.

3. Appropriateness of the procedures given during the training periods as well as the relative emphasis given to various procedures.

4. Methods of conducting training sessions with emphasis on the realism and the adequacy of the buildup to emergencies.

When personal signatures are required on questionnaires, students tend to try to please the instructor with their answers, no matter how much assurance is given that their criticisms will not be used against them. This tendency can be reduced by not requiring the students to put their names on the questionnaire. Truth, even when it hurts, should be sought with such questionnaires. It must be realized that student opinions are not full substitutes for scientific investigations of the worth of a training device or a training program. When opinions are obtained from a sufficiently large group of students, they can be a useful and readily available source of information. However, they may be misleading if they are not properly interpreted.

Gathering Information From Outside Sources

Some of the information needed to keep a training program up to date must be obtained from sources outside the training unit. Supervisory, instructor and operator personnel should have the most recent information available on current procedures and the operation of the actual equipment. The following are some of the publications which are helpful:

1. The Pilot's Handbook for the aircraft simulated.
2. Aircraft manufacturers' publications.
3. Pertinent Bureau instructions.
4. Naval Aviation News.
5. Publications of the U.S. Naval Aviation Safety Center, NAS, Norfolk, Virginia.
6. Federal Aviation Agency publications such as the Flight Information Manual and Air Traffic Control (ATC) Procedures for the Control of Air Traffic.
7. Submarine and surface ship operating directives.

METHODS FOR IMPROVING TRAINING QUALITY

Accurate and well-defined information in the areas mentioned in the preceding paragraphs serves as the basis for initiating continuing and realistic administrative actions for improving the training program. In fact, many of the methods of collecting information, by their mere use, tend to improve the quality of training. Methods which have proved successful in effecting improvement in synthetic device programs are discussed below.

Staff Meetings

Staff meetings are one of the most useful and efficient methods for making improvements in a program. During these meetings Squadron/Ship training officers, the division officer, leading chief, and/or the petty officer in charge of TD operators can discuss existing deficiencies in the program and can initiate corrective measures. Most of the meetings will require only the presence of the instructors/operators, but for certain topics it may be advisable to have maintenance personnel also present so that they can gain an understanding of how good trainer maintenance can help solve the problem involved. Listed in the following paragraphs are some suggested topics for staff meetings.

STAFF RECOMMENDATIONS.–Supervisors should encourage instructor/operator and maintenance personnel to make any recommendations they have for improving the program. These recommendations should be freely discussed and a decision made by the supervisor on whether or not to incorporate them into the program.

INSTRUCTOR/OPERATOR DEFICIENCIES.–Procedures that are being incorrectly taught should be called to the attention of the instructors/operators. In a staff meeting, this must be done in such a way that even the poorest operator/instructor will not feel he is being ridiculed. Criticism should always be constructive. Telling a group that they need to improve does little good unless they are also given some suggestions on how to improve. Whenever possible, operators/instructors should be complimented on above-average performance. Operators/instructors whose performance is poor should be individually interviewed so that their specific deficiencies may be pointed out to them and suggestions for improvement given.

PROCEDURE REVIEWS.--Reviews of the procedures taught in the trainer should be held periodically to ensure that everyone is teaching those procedures correctly. Whenever revisions are made, they should be discussed thoroughly and immediately incorporated into the program. Supervisors should be certain that they make definite decisions on controversial topics discussed at staff meetings. If this is not done, or if these decisions are not emphasized, considerable confusion may result.

On-The-Job Training

Good on-the-job training for operators/instructors and maintenance personnel is essential. Suggestions for training maintenance personnel were given earlier in this chapter. Training for instructors/operators should include operating the trainer through each procedure they will be required to instruct/operate, observing an experienced instructor/operator, and finally, instructing/operating under the supervision of an experienced instructor. When possible, indoctrination time in the actual equipment being simulated (ship, submarine, or aircraft) should also be given.

Obtaining Student, Station, and Command Support

To conduct an effective training program, training personnel must actively seek and secure the support of student, station, and command personnel. Without their support, little can be accomplished.

Since new developments are constantly being made in the manufacture of training devices, the officers in charge of the training program at a station or in a squadron may not be fully aware of the capabilities of operational training devices. As a training program is being planned, it is often helpful to provide familiarization in the equipment to key personnel. These people should be shown the nature of the training that can be given, and should be advised as they set up a syllabus so that the greatest possible coordination between training in the simulator and training in the actual equipment will be achieved.

CHAPTER 4

PRINCIPLES OF AIR CONDITIONING

The term "air conditioning" is often erroneously construed to mean the cooling of a given mass of air. When correctly defined, it is the process of treating air so as to control its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space. It can be stated that true air conditioning requires mechanical ventilation, addition of heat, removal of heat, control of humidity conditions, and filtering.

The construction and operation of most electronic equipment require controlled temperature and humidity conditions. To obtain the desired atmospheric control from air-conditioning equipment requires space, a source of power, and routine maintenance. Training devices, because of their limited space, usually utilize compact units. This normally increases the maintenance requirements of the equipment. The most widely accepted configuration for training devices is the self-contained air-conditioning unit; that is, complete air handling, cooling, heating, humidifying, and dehumidifying equipment is designed to fit into one compact package.

This chapter is intended to provide the TD with a general knowledge of air conditioning. Subjects discussed include air-conditioning requirements, theory of operation, and maintenance. Air-conditioning equipments will vary from trainer to trainer, but the general theory remains the same.

The few TDs who require a more in-depth coverage of the subject can find the information in *Refrigeration and Air Conditioning*, NAVPERS 16163 (Series), or the manuals supplied with the specific equipments they are working on.

REFRIGERANTS

The system which provides mechanical cooling is commonly referred to as the refrigeration system. The refrigeration system, whether it is a part of an air conditioner, a refrigerator, or water cooler, operates on the same general principle using a refrigerant.

Mechanical refrigeration systems use, as a primary refrigerant, some liquid that has a boiling point lower than water but, in changing from liquid to vapor at low pressures and temperatures, absorbs a lesser quantity of heat. Most refrigerants commonly used today require close-to-atmospheric pressures in the system, thus, leaking tendencies and overwork of compressors are reduced to a minimum.

REFRIGERANT-12

Dichlorodiflouromethane is known as Refrigerant-12, or R-12. In some texts, you will find it referred to as Freon 12, Genetron 12, or Isotron 12. In training courses, it is generally called Refrigerant-12. It has a boiling point of minus 21.7° F and would immediately boil if exposed to ordinary room temperature and atmospheric pressure. It must therefore be kept under pressure if it is to be maintained in a liquid state; this pressure will vary according to the ambient temperature. Its freezing point (minus 247° F) is a temperature not likely to be encountered in operating conditions.

Refrigerant-12 has now replaced to a great extent such refrigerants as ammonia, sulfur dioxide, or methyl chloride, which because of their toxic and explosive character have caused many fatalities.

The chief advantages of this refrigerant are:

1. It is odorless and tasteless in concentrations of less than 20 percent by volume in air.

2. It is nontoxic; but by reducing the oxygen content in a working space, it can cause suffocation.

3. It is nonexplosive and nonflammable; although it decomposes in the presence of an open flame, forming irritating and toxic gases, it will not ignite.

4. It is noncorrosive in contact with the metals that are commonly employed in refrigeration units; it will, however, corrode magnesium and aluminum alloys that contain magnesium.

5. It is chemically stable up to at least 1,000° F; above that temperature, it decomposes, forming corrosive and poisonous products.

6. It acts as a solvent, loosening and removing particles of dirt, scale, or oil within the system. However, it will eat away natural rubber gaskets; therefore, neoprene or some other synthetic rubber must be used.

7. It mixes readily with oil, and thus simplifies the lubrication of the plant by acting as a carrier of oil to moving parts and as an aid in returning the oil from the evaporator. This last characteristic is important, since an excess of oil in the evaporator will form an insulating film between the refrigerant and the inside surface of the evaporator.

The disadvantages of Refrigerant-12, from an operating standpoint, are:

1. It has a low latent heat, and, as a result, absorbs only about 69 Btu for every pound of refrigerant that boils off in the evaporator at 5° F. This low latent heat necessitates the circulation of a large volume of refrigerant per ton of refrigeration.

2. In concentration of 20 percent or more, Refrigerant-12 produces a phosgene gas if exposed to an open flame.

3. In its liquid form, Refrigerant-12 can cause severe frostbite (extra care must be taken to avoid this). Since the refrigerant has no noticeable odor, leaks may escape notice.

The disadvantages of the low latent heat (60 Btu per pound of refrigerant) can be emphasized by comparing it with the refrigeration ton (12,000 Btu per hour). Thus, a 1-ton unit would have to boil off a minimum of approximately 173 pounds of refrigerant per hour to maintain the cooling capacity of 12,000 Btu per hour.

Because of the capacity of Refrigerant-12 to absorb water, utmost caution is necessary to prevent the entrance of water (or water-laden air) into the system. Any excessive moisture in the system can cause freezeups at the expansion valve. This characteristic is one that Refrigerant-12 shares with all refrigerants whose boiling point is below 32° F.

REFRIGERATION CYCLE

OPERATION

As the refrigerant flows through the primary (or basic) refrigeration components, it assumes four different and distinct states of character. These four states of refrigerant (fig. 4-1) are:

1. Low temperature, low pressure gas (input side of the compressor).
2. High temperature, high pressure gas (output side of the compressor).
3. High temperature, high pressure liquid (output side of the condenser and liquid receiver).
4. Low temperature, low pressure liquid (output side of the expansion valve).

The following sequence of operation traces the flow of refrigerant through its cycle and explains where the changes take place.

When the compressor starts, it draws refrigerant gas from the low-pressure (suction) side of the refrigeration system. Mechanical action of the compressor changes the refrigerant into a high-pressure gas. This gas is normally cold when it enters the compressor, but it becomes hot during compresion.

The hot high-pressure gas leaves the compressor's high-pressure (discharge) side and flows directly to the condenser coil. The heat, produced when the gas was compressed and which was removed from the conditioned space,

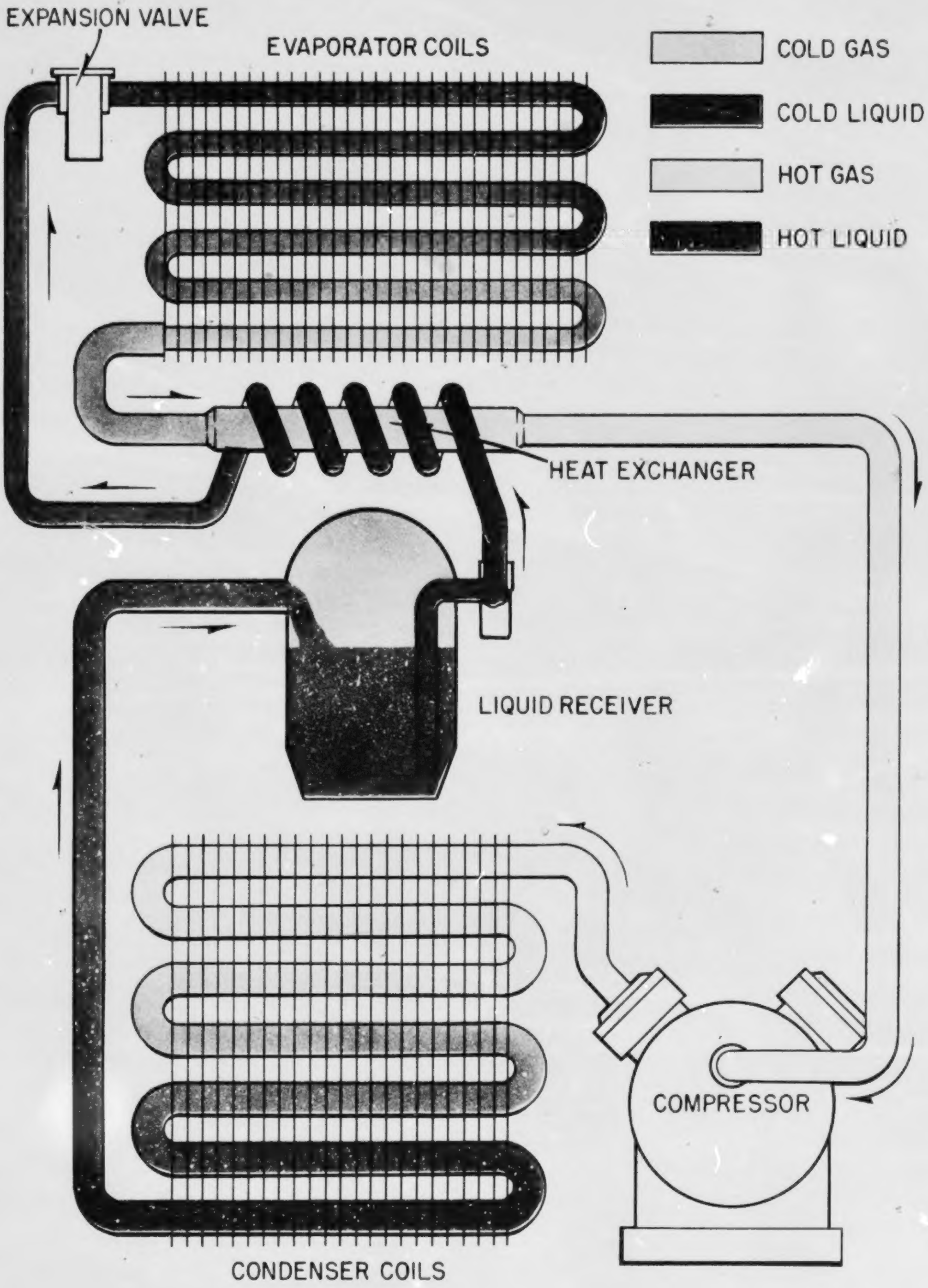


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Figure 4-1.–Fundamental refrigerant cycle.

is dissipated with a finned coil by the airstream drawn through this coil by the condenser fan. This cooling effect gradually changes the high-pressure gas into a high-pressure liquid.

From the condenser coil, the refrigerant flows to the receiver which acts as a reservoir for storing the liquid refrigerant. After leaving the receiver, the high-pressure liquid flows through the thermostatic expansion valve. Here the refrigerant is changed into a low-pressure liquid and is metered into the evaporator coil.

Upon entering the evaporator coil, the low-pressure liquid changes (boils) to a low-pressure gas. This change, from liquid to gas, produces a cooling effect within the evaporator coil and the coil becomes cold. (This is an application of the latent heat of vaporization.) A stream of air is directed over the cold coil. The air is cooled and then directed to the space to be cooled.

After leaving the evaporator coil, the refrigerant returns to the low-pressure (suction) side of the compressor.

The foregoing cycle is repeated as long as the compressor is operating. As can be seen from the above, the flow of refrigerant is from the compressor to the condenser coil, then to the receiver, to the expansion valve, to the evaporator coil, and back to the compressor.

MAJOR COMPONENTS

Compressor

The compressor is used to remove (draw) gas from the evaporator and increase the pressure of the gas sufficiently for operation of the remainder of the system. Thus, by increasing the pressure of the gas, the temperature is raised above that of the medium (air or water) surrounding the condenser, permitting heat to flow to the medium.

The size and the type of compressor vary according to the installation and the requirements of the air-conditioning system. Compressors may be divided into three general groups–reciprocating, rotary, and centrifugal. A second classification, as to type of compressor, is the open, semihermetic, and full-hermetic type. The function of the compressor is the same in all three types, but the mechanical means for accomplishing this task differs considerably.

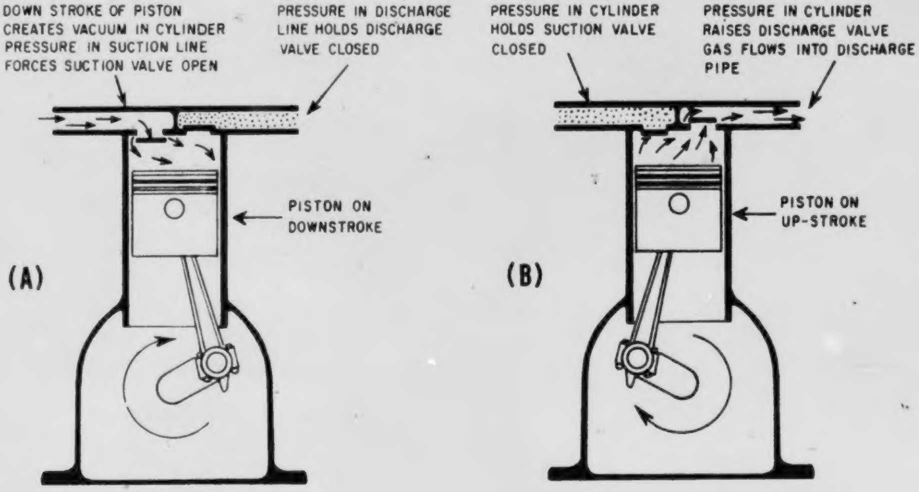
OPEN RECIPROCATING TYPE.–This type of compressor is driven by an external means, which is normally belt-driven or direct-driven through coupling. One of the simplest ways of achieving high gas pressures is to draw a large quantity of gas into a cylinder through an intake or suction valve (fig. 4-2) by means of the partial vacuum produced by the downward movement of a piston. The piston is actuated by a crank arm or connecting rod attached to a crankshaft, which is rotated by the external driving force.

As the piston is moving down toward its lowest position, the cylinder is completely filled with low-pressure gas. As indicated in figure 4-2 (A), the suction (intake) valve opens when the pressure inside the cylinder is less than the pressure in the suction line leading to the cylinder. A common pressure at the suction valve is about 37 psig (pounds per square inch gage).

When the piston has reached the lowest point of its travel, it begins to move upward (fig. 4-2 (B)), and the intake (suction) valve closes. The intake valve closes when the pressure inside the cylinder becomes greater than that in the suction line.

The gas that has been compressed is delivered to the high-pressure (discharge) line through the discharge valve. As the piston moves upward, the valve opens when it senses that the pressure inside the cylinder is higher than that in the high-pressure line. A common pressure at the discharge valve would be about 126 psig. The valves, therefore, serve as one-way traffic-flow controllers; they permit the gas to flow in one direction only, and only when the pressures are of the correct amount.

The open type compressor has the advantage of supporting large systems. Also, the power source can be any prime mover. The fact that the compressor is driven by an external source of power through a shaft creates operating disadvantages. Sealing around the shaft must be maintained to prevent gas on the inside of the compressor body from leaking outward into the atmosphere. The exposed belt drive or rotating couplings may prove dangerous to operating


DOWN STROKE OF PISTON CREATES VACUUM IN CYLINDER PRESSURE IN SUCTION LINE FORCES SUCTION VALVE OPEN
PRESSURE IN DISCHARGE LINE HOLDS DISCHARGE VALVE CLOSED
PISTON ON DOWNSTROKE
(A)
PRESSURE IN CYLINDER HOLDS SUCTION VALVE CLOSED
PRESSURE IN CYLINDER RAISES DISCHARGE VALVE GAS FLOWS INTO DISCHARGE PIPE
PISTON ON UP-STROKE
(B)

225.183

Figure 4-2.–Operating cycle of a reciprocating compressor.

personnel. This type of compressor system requires considerable space for operating.

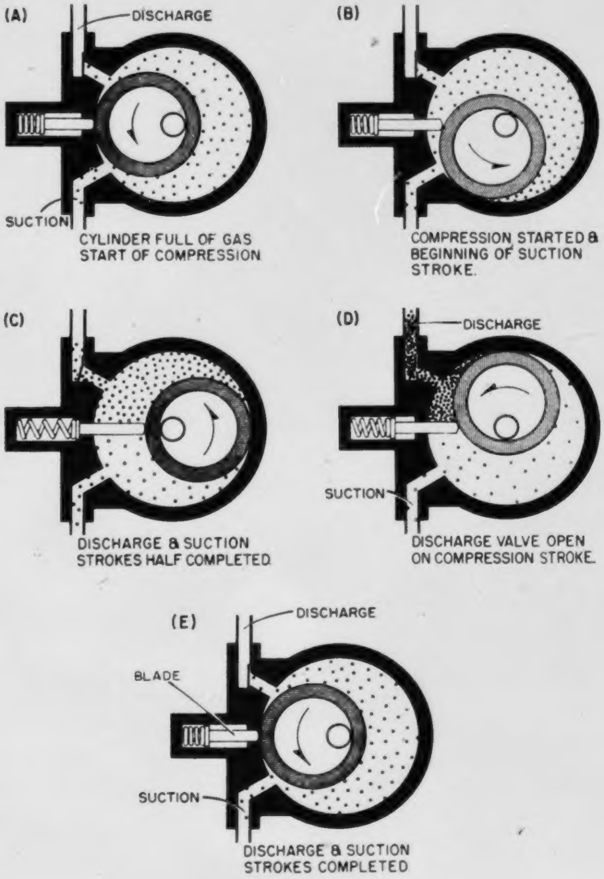
SEMIHERMETIC RECIPROCATING TYPE.–This type compressor has the compressor and direct drive motor housed within one casing or casting. The operation of the compressor is the same as the open type compressor. Both units are housed in a common enclosure which eliminates some of the disadvantages of the open type unit. The weight and space consumed are much less than that required by the open type compressor.

FULL-HERMETIC RECIPROCATING TYPE.–The full-hermetic unit is a completely closed motor and compressor welded into a pressed steel casing. This prevents any type of field maintenance and requires that servicing be performed at very specialized compressor overhaul centers, normally the compressor manufacturer's plant. This type compressor has all the advantages of semihermetic compressors plus additional weight saving because of the much lighter pressed steel casing.

ROTARY.–Another common type of compressor is the rotary type. This has some distinct advantages as far as vibration and moving parts are concerned. The materials used in construction are very similar to those of the reciprocating pump, but its operation is different. The major difference is that the pumping effect is produced by a rotary motion rather than a reciprocating motion.

The operation of the stationary blade compressor is illustrated in figure 4-3. The shaft rotates in a chamber so that the eccentric or offcentered disc rubs constantly against the outer wall of the chamber. Referring to figure 4-3, the sequence of operation can be followed. With the chamber filled with gas (A), the eccentric starts to rotate. As the eccentric rotates (B), gas imprisoned ahead of the eccentric is compressed and the void behind the eccentric sucks low-pressure gas into the chamber in preparation for the following cycle. As rotation continues ((C), (D), and (E)), the imprisoned gas is compressed into a smaller space, building up the pressure and temperature, and finally forcing the gas into the high-pressure side (or discharge side) of the system.

Another version of the rotary type compressor is the rotating blade. It differs from


(A)
DISCHARGE
SUCTION
CYLINDER FULL OF GAS START OF COMPRESSION
(B)
COMPRESSION STARTED & BEGINNING OF SUCTION STROKE.
(C)
DISCHARGE & SUCTION STROKES HALF COMPLETED
(D)
DISCHARGE
SUCTION
DISCHARGE VALVE OPEN ON COMPRESSION STROKE
(E)
DISCHARGE
BLADE
SUCTION
DISCHARGE & SUCTION STROKES COMPLETED

244.6

Figure 4-3.—Stationary blade rotary compressor.

the compressor described above in that one or more pairs of blades are rotated in place of the eccentric. As these blades rotate, they trap low-pressure gas from the suction line and force the gas into smaller and smaller spaces until, at the discharge lines, the gas leaves as a high-pressure, high-temperature gas.

Compressor Motors

The driving mechanism or the source of power for compressor units is usually an electric motor. The type and the size of the motor vary with the requirements of the particular installation. Two general types of motors used are the open and sealed motors. The open type, normally a capacitor motor, is a common type motor used in the air-conditioning field. See *Basic Electricity*, NAVPERS 10086 (series) for a complete discussion of electrical motors.

The troubles encountered in the capacitor type motor are few, and they deal mainly with the mechanical condition of the motor. There is a possibility that the centrifugal switch may become worn. Also, an open or short circuit may occur in the capacitor or in the field windings. The mechanical troubles encountered are common to most types of motors. The most common of these are:

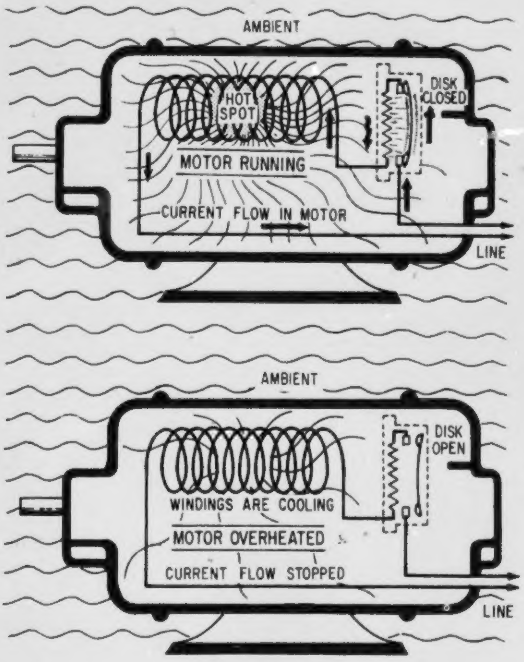
1. Worn bearings.
2. Excessive end play.
3. Excessive vibration.
4. Dirty.
5. Worn motor mounts.

Very frequent starting of the motor may result in overheating, which many times will cause the capacitor and/or the windings to fail. If the motor will not start, but simply has the characteristic hum, it is a sign that the capacitor or the centrifugal switch points have failed, or the starting winding is open. It is a simple matter to substitute a good capacitor for the questioned one. If the motor still does not start, the trouble is possibly in the centrifugal switch or the starting winding. A continuity check should quickly determine the fault.

The basic operation of the hermetic type motor is essentially the same as the open type. There are some definite differences because of the motor being mounted in a sealed container (fig. 4-4) with the compressor. Brushes and/or open points cannot be used in the hermetic motor because the arcing would gradually disintegrate the refrigerant and the oil in the unit. Therefore, an external means must be used to disconnect and connect the various windings, and all torque must be developed by induction only. The electrical terminals which carry the circuit through the dome (container) must be electrically insulated from the dome; they must also be leakproof.

The higher starting torque required for those units which start under load necessitates the use of large conductors in the starting circuit. This required starting torque is usually obtained by using one of several electrical devices. Usually, manufacturers attempt to provide starting power equal to twice the running power. In other words, the attempt is to have a 1/6-horsepower motor produce one-third horsepower during starting. Likewise, various methods are used to disconnect the special starting devices after the motor has approached its full speed.

Servicing of hermetic motors may be divided into two major sections—external and internal servicing. Most of the hermetic motor troubles are external and may be traced to defective wiring or control devices. Occasionally a unit will not start, even though all the electrical tests indicate the unit is in good condition. This stuck condition may be caused by the unit standing idle for a long time, a particle of dirt, or an abnormal amount of liquid refrigerant in the compressor. Three methods which may break loose the stuck unit are:



244.10

Figure 4-4.—Overload protection for an open type motor.

1. Connecting the power source directly to the motor connections, thus bypassing the control circuitry.

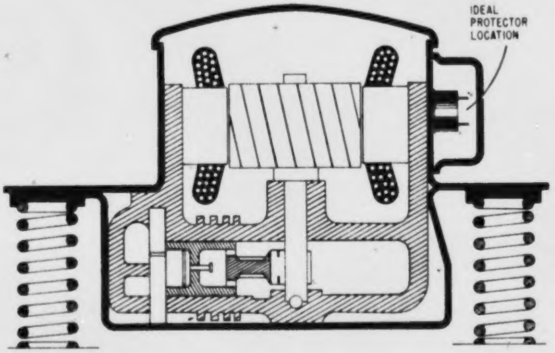
2. Using above normal voltage applied to the motor connections. This method should only be used for a short period of time.

3. Reversing the rotation of the unit; that is, making the motor run backward.

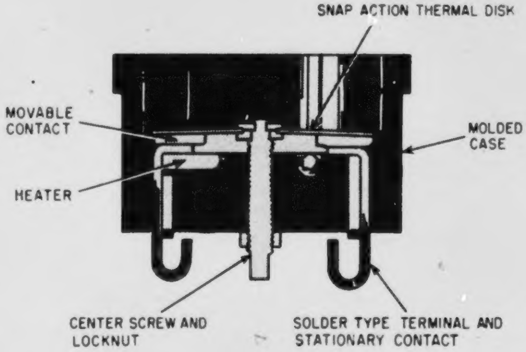
Motor-compressor systems have safety devices installed that open the electrical circuit if the motor draws too much current, if the motor overheats, and/or if the compressor becomes too hot. Other sources of excessive heat occur from high exhaust fan temperatures, poor circulation, and friction.

One type of safety device used in open type motors uses a heating coil and a bimetal contact strip. (See fig. 4-4.) If excessive current flows through the heating coil, it heats the bimetal strip. The bimetal strip bends when heated and opens the electrical circuit to the motor. The motor will not start again until the bimetal cools sufficiently to again complete the circuit. The bimetal strip will bend and open the circuit if heat from any source is high enough to damage the motor or compressor.

For the sealed hermetic type motor-compressor system, the bimetal safety device is installed in the dome. (See fig. 4-5.) This type of bimetal disc is called a snap-action thermal disc. (See fig. 4-6.) When the bimetal disc reaches a temperature that causes it to snap upward, the circuit is opened. Thus the bimetal disc is temperature sensitive of heat from the motor, the compressor, and the current drawn by the motor.



244.11
Figure 4-5.—Overload protection for a sealed hermetic motor compressor.



244.12
Figure 4-6.—Bimetal disc protector.

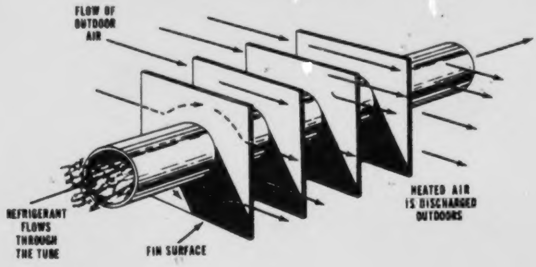
Condensers

The function of the condenser coil (fig. 4-1) in a refrigeration cycle is to convert the hot refrigerant gas discharged from the compressor into a liquid state before it is ready for use again in the evaporator. The condenser accomplishes this by removing heat from the hot gas to cause it to condense at the pressure existing in the high-pressure side of the system. The heat-dispelling effect of the condenser must be equivalent to the sum of the following:

1. The amount of heat absorbed by the refrigerant in the evaporator.
2. The amount of heat caused by the friction of the gases going through the suction (low pressure) line.
3. The amount of heat absorbed by the gases while increasing in pressure by the compressor.

There are two general types of condensers—the air-cooled and the water-cooled condenser. The condenser (fig. 4-1) is many sections of tubing connected as a continuous pipe and mounted within a block of thin waferlike metallic fins.

AIR-COOLED.—The air-cooled condenser (fig. 4-7) utilizes ambient (surrounding) air, and by means of fans pushes or pulls (preferably


FLOW OF OUTDOOR AIR
REFRIGERANT FLOWS THROUGH THE TUBE
FIN SURFACE
HEATED AIR IS DISCHARGED OUTDOORS

225.187

Figure 4-7.–Air-cooled condenser.

pulls) the air through the condenser block of pipes and fins. Refrigerant cooling is obtained by adequate condenser surface and maximum air circulation over the outside condenser coil surfaces. Maximum condenser surface is obtained by closely spaced fins on the coils. The coil and fan arrangement is similar to an automobile radiator.

The air-cooled condenser is the type of condenser with which the TD will normally be concerned. It is utilized in window type installations and in mobile trainer units. The maintenance required is relatively minor and consists mainly of keeping the coil and fins clear from dust and dirt. This cleaning can be done best with a vacuum cleaner and soft-haired brush.

WATER-COOLED.–Water-cooled condensers are commonly used in air-conditioning systems installed in trainer buildings. This type of system is generally maintained by Public Works and will not be discussed in this chapter.

Receiver

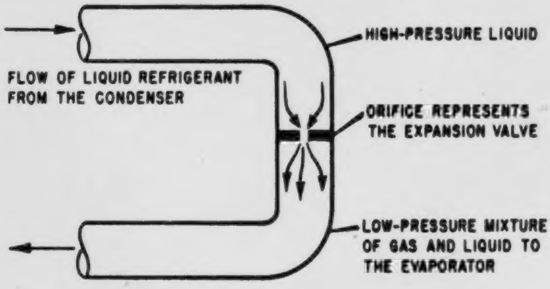
The receiver (fig. 4-1) is a storage tank for liquid refrigerant. The high-pressure liquid from the condenser enters the receiver tank at a coupling near the top. The departing liquid leaves through a coupling located in the upper portion of the tank. This mounting is placed here for convenience because at the outlet of the receiver there should be a service valve, commonly called the receiver or king valve. It is essential that the line leading away from the receiver contain only liquid refrigerant. A "quill" is connected internally to the receiver valve which dips down to the bottom of the receiver tank (fig. 4-1), assuring that liquid refrigerant enters the quill and leaves the receiver.

Expansion Valve

The function of an expansion valve is to change the high-pressure liquid to a low-pressure liquid. The output of the expansion valve is automatically controlled to ensure that the correct quantity of refrigerant to keep the cooling unit operating at maximum efficiency and without overloading the compressor is passed. (See fig. 4-1.) The action of the valve is very similar to a spray nozzle; and while the compressor is running, the liquid refrigerant is sprayed into the cooling unit tubing.

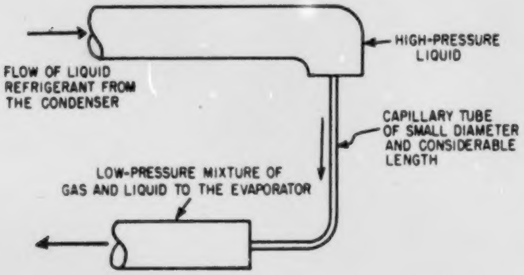
Many different forms of expansion valves are found in air-conditioning equipment. Some of them operate when a temperature change occurs in the refrigerant flowing past the valve, and others operate when a pressure change occurs. In principle, regardless of the complications of any particular device, the valve is a simple device as illustrated in figure 4-8. When a gas or liquid is squeezed through a small opening and then allowed to expand into a larger chamber, the pressure decreases.

A modification of the valve orifice that has come into extensive use in small refrigeration machinery is the capillary tube. Essentially, the


HIGH-PRESSURE LIQUID
FLOW OF LIQUID REFRIGERANT FROM THE CONDENSER
ORIFICE REPRESENTS THE EXPANSION VALVE
LOW-PRESSURE MIXTURE OF GAS AND LIQUID TO THE EVAPORATOR

225.186

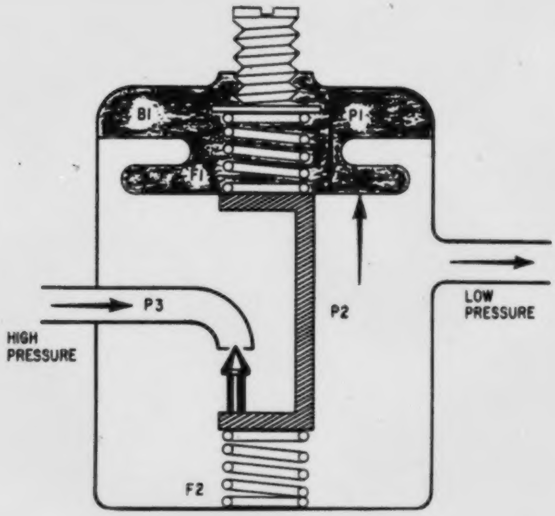
Figure 4-8.–Expansion valve principle.


FLOW OF LIQUID REFRIGERANT FROM THE CONDENSER
HIGH-PRESSURE LIQUID
CAPILLARY TUBE OF SMALL DIAMETER AND CONSIDERABLE LENGTH
LOW-PRESSURE MIXTURE OF GAS AND LIQUID TO THE EVAPORATOR

225.191
Figure 4-9.—Capillary tube as an expansion valve.

orifice (fig. 4-8) is replaced by a long tube of extremely small diameter as shown in figure 4-9. The main advantage of the capillary tube is that no moving parts are required. Each capillary tube must be specially designed to fit a particular size unit. It is essential that clean refrigerant be used which will not clog the tube (which may be as small as 0.04 inch in diameter and several feet long).

The pressure method of operating an expansion valve is illustrated in figure 4-10. The figure shows a flexible bellows B1 connected to the needle of a needle valve and having the cooling unit (evaporator) pressure P2 pushing up on the inside, and atmospheric or confined gas pressure P1 pushing downward. The spring force F1 tends to open the valve, while F2 tends to close the valve. It can be seen that as the pressure in the cooling coil (low-pressure line P2) decreases, the difference in pressures forces the bellows down toward the valve body. The valve body is connected to the needle and opens the needle valve, allowing some liquid refrigerant to spray into the low-pressure line and into the cooling coil (evaporator). The opening of the needle valve allows pressure P2 to push the bellows B1 upward until the needle valve is again seated which shuts off the high-pressure liquid P3.

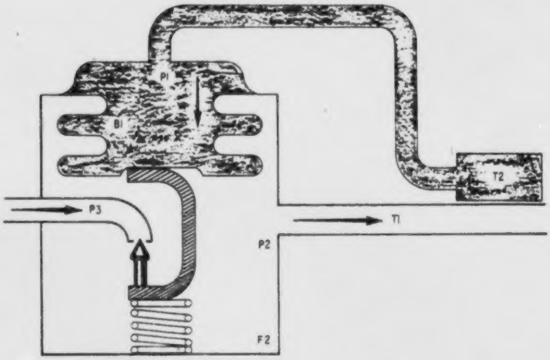


225.192
Figure 4-10.—Pressure expansion valve.

Opening of the expansion valve occurs when the compressor is running and reducing the pressure. The expansion valve prevents flooding the low-pressure side when the compressor is running. As soon as the evaporating refrigerant vapor reaches the end of the cooling unit (evaporator) tubing, the motor control safety valve becomes too cold and stops the motor. This allows the low-pressure line to build up sufficient pressure (P2 of fig. 4-10) to close the needle valve in the expansion valve.

The pressure type expansion valve is adjustable to permit the opening of the needle valve over a varying range of pressures. Valve adjustments must be made for varying altitudes as their operation is influenced by atmospheric pressure. Also, different refrigerants require different settings. The valves are made in a variety of designs, and adjustment procedures for any one particular type are normally furnished by the manufacturer and should be closely followed by the maintenance man.

The thermostatic expansion valve is an improved type of expansion valve, having a thermostatic or temperature sensitive bulb mounted on the evaporator tubing (fig. 4-11). The bulb T2 is connected into the bellows or diaphragm B1 by very small tubing. This void is filled with the same refrigerant as used in the compressor system. As the bulb T2 becomes warm, the pressure of its refrigerant expands and builds up pressure in the diaphragm B1 power



225.193

Figure 4-11.—Thermostatic expansion valve principles.

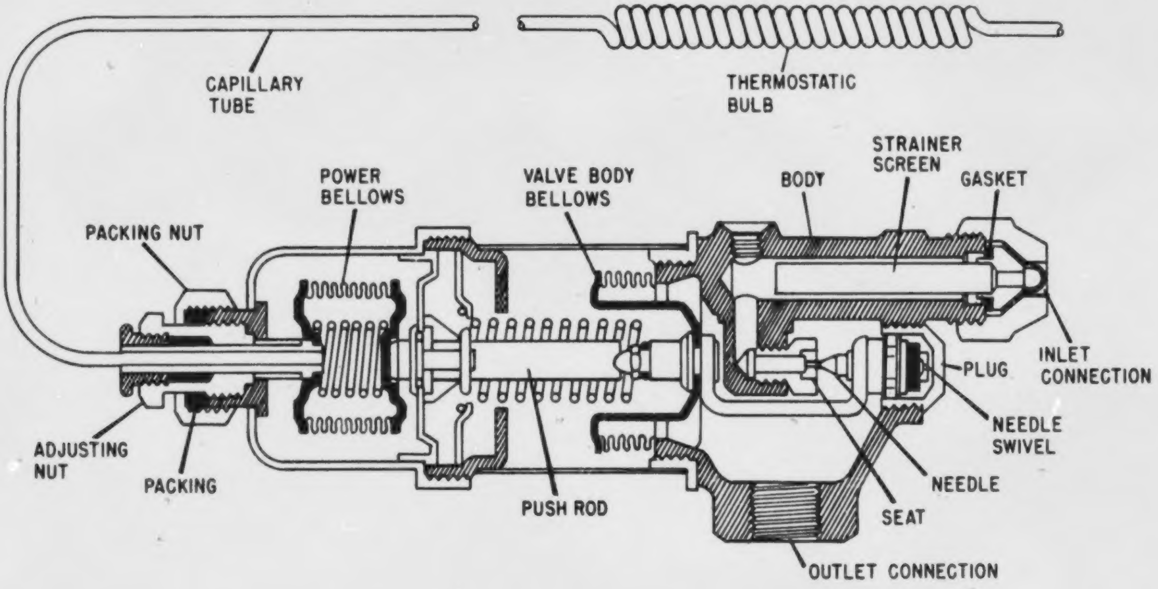
element. The bellows then expand, forcing open the expansion valve needle, and liquid refrigerant (P3) flows into the cooling coil (evaporator) line T1.

After the cooling coil (evaporator) is cooled, the suction line to the compressor begins to cool. The bulb T2 also cools, pressure within it decreases, and the fluid within it contracts. This causes a contraction of the bellows B1, which in turn causes the diaphragm to close the valve needle.

The actual parts for this type of expansion valve are illustrated in figure 4-12. The principle of operation is essentially the same as the basic illustration (fig. 4-11). The assembly functions to keep the cooling coil (evaporator) supplied with refrigerant. This is different from the pressure automatic expansion valve, shown in figure 4-10, which maintains a specified low pressure. The thermostatic expansion valve does not enter at all into the regulation of pressure on the low-pressure side of the system because the compressor establishes its own pressure upon the refrigerant.

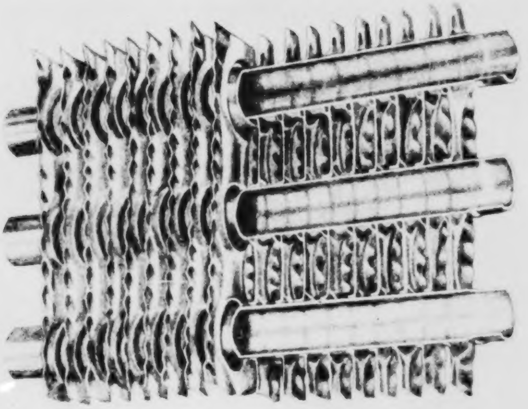
Evaporator (Cooling Coil)

The evaporator (fig. 4-13) consists of a coil of tubing mounted in a block of thin metallic fins. The refrigerant travels from the expansion valve in the form of liquid and gas to the cooling



225.194

Figure 4-12.—Thermostatic expansion valve.



225.189

Figure 4-13.—Evaporator.

coil (evaporator). The evaporator coil is cooled by this change of state of the refrigerant. The air to be cooled is then directed over the coil, and cooling of the air is accomplished.

As the warm air is passed over the outside of the evaporator, heat is transmitted to the fin surfaces, to the circular pipe, and then to the refrigerant. The heat applied to the outside of the tube causes the refrigerant to boil. As a result of boiling, the liquid refrigerant changes into a gas, but remains at the same low pressure. This gas is eventually drawn back to the suction side of the compressor. Also, as the warm humid air comes into contact with the cold metal, the air is cooled below its dew-point which results in water droplets and partial dehumidification.

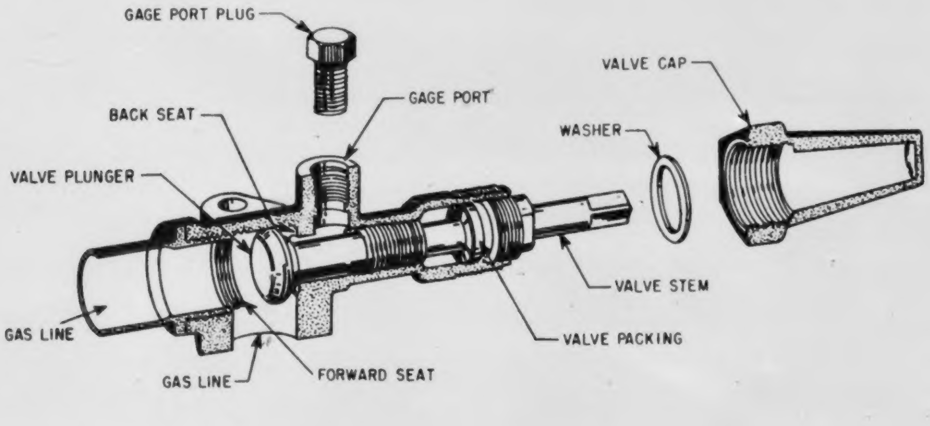
REFRIGERATION ACCESSORIES

There are various accessories that can be added to the major components to provide either simplified maintenance or increased efficiency without changing the function of the refrigeration system.

SERVICE VALVES

The service valves, referred to as the head and suction valves, are utilized for maintaining and charging the system. The head valve is mounted on the high-pressure port of the compressor, and the suction valve is mounted on the low-pressure side. The construction of the valves and their method of operation are identical. (See fig. 4-14.) However, they differ in size, use, and placement.

The valve cap for a compressor service valve contains a gasket which forms a refrigerant tight fit between valve cap and valve body. The valve cap and gasket must be removed to position the valve plunger. The valve plunger is normally



225.190

Figure 4-14.—Service valve.

positioned in the forward seated, back seated, or cracked position. Always use the wrenches provided with the air conditioner for adjusting the service valves.

To forward seat a service valve (fig. 4-14), turn the valve stem clockwise as far as it will go. This puts the plunger to the left and tight against the forward seat which stops gas flow at this point.

To back seat a service valve (fig. 4-14), turn the valve stem counterclockwise as far as it will go. The valve plunger is now to the right and tight against the backseat. The gas line is now completely open.

To crack a service valve (fig. 4-14), first back seat and then turn the valve stem one-fourth turn clockwise. This moves the valve plunger slightly to the left which allows gas to flow into the gage port.

To install a pressure gage in a service valve, back seat and remove the gage port plug; then insert the gage and crack the service valve so the gage will read.

Never operate the compressor with the head service valve forward seated. This condition blocks the output of the compressor, allowing the pressure of the compressor to build up sufficiently to become dangerous to personnel and will damage the compressor.

LIQUID LINE SIGHT GLASS

The sight glass is a visual indicator used for maintenance purposes to visually determine the condition of the refrigerant entering the thermal expansion valve. The sight glass should be located on the inlet side and as close to the thermal expansion valve as possible. The appearance of the refrigerant passing through the sight glass should be clear. If the sighting should indicate a cloudy or milky appearance, this indicates that the level of refrigerant is low. The milky appearance is caused by tiny gas bubbles passing through the system mixed with the liquid refrigerant.

RECEIVER VALVE

The receiver valve, referred to as the king valve, is located on the output side of the receiver tank. This valve is used when it is necessary to trap the refrigerant in the receiver and condenser lines.

HEAT EXCHANGER

The heat exchanger (fig. 4-1) is employed to obtain better efficiency. Hot liquid from the receiver, which is to be cooled in the evaporator, transfers heat to the cool suction gas which is on its way back to the compressor. The heat exchanger is constructed to carry the liquid in the smaller of the two tubes which is mechanically connected to the large tube carrying the cool suction gas. The two tubes are connected into the system so that the inputs and outputs are in the same direction.

DRIER STRAINER

The drier strainer, also called a catchall, is employed to remove any foreign matter or water from the refrigerant. Foreign material could clog small openings, and water could freeze in the expansion valve. It is normally located between the expansion valve and heat exchanger. The refrigerant passes through a filter cloth where foreign material is trapped, and then through a porous material where water is absorbed from the system.

When maintaining an air-conditioning system, if the drier strainer should feel cooler than the liquid line entering the drier, it is an indication that the unit should be replaced. The connecting ports of the filter are marked in and out to ensure proper connection to the system.

AIR FILTERS

Cleanliness within any confined space is important. Two types of filters commonly used in the removal of dust, bacteria, and odor are the dry filter and viscous filter.

The dry filter which removes the dirt by passing the air through small openings in felt, spun glass, or paper screens is generally of a disposable type. When this filter becomes loaded with dirt, it is discarded.

The viscous filter depends on the dirt adhering to a surface covered with a viscous fluid or oil and is generally of the permanent type filter. When this type filter is dirty, it can be reused only if it is re-treated with a viscous fluid or oil. The cleaning process for this type filter is:

1. Gently tap the filter to remove loose dirt.
2. Wash with hot water applied to the dirty side of the filter and flush out dirt and old adhesive.
3. Shake off excess water and allow the filter to dry.
4. After the filter is dry, it should be treated with a commercial filter adhesive.

The advantage of using a commercial preparation for treating the filter is the active germicidal and fungicidal ingredients which are contained in the fluid. If a commercial preparation is not available, a very light oil can be substituted. In applying the filter adhesive, a liberal coating should be placed over the entire surface of the filter, but care should be taken to avoid excess.

Proper maintenance of filters is a very important task for the efficient operation of any air-conditioning system. As can be realized, when the cycle of operation is reviewed, the passage of air is essential for the successful operation of any air-conditioning system. When performing preventive maintenance checks, always inspect the filter with special attention to the following:

1. Check the condition of the disposable filters, looking for thin spots and holes as well as dirt. If spots or holes are present, the filter should be replaced.
2. If dirt has accumulated on any filter, it should be cleaned, treated (if a permanent filter), and reinstalled. A clogged filter reduces airflow and is a source of dirt.
3. If over a prolonged period of time very little dirt accumulates on a permanent viscous filter, then the adhesive coating should be carefully checked. This condition probably does not indicate a clean condition, but rather the fact that the adhesive coating is not doing its job. The filter should be removed, cleaned, and recoated.

CONTROLS

Air-conditioning equipment utilizes two distinct types of controls. These controls may be classified as the operating and safety controls. The operating controls maintain the desired conditions, while the safety controls are used to prevent damage to the equipment.

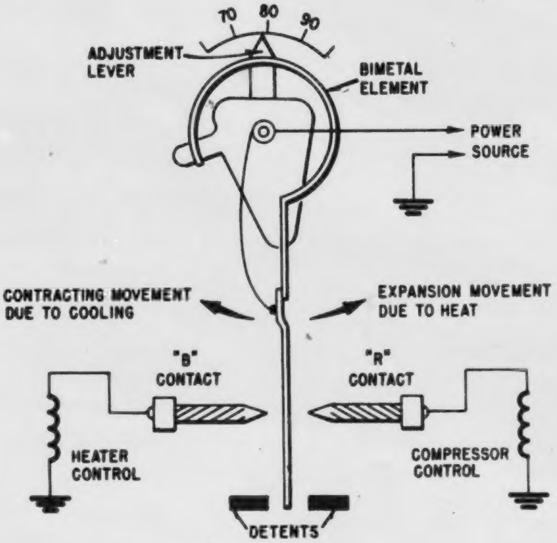
OPERATING CONTROLS

The operating controls of an air-conditioning system may be as simple as turning on and off a heater and turning on and off the compressor to control cooling. Some systems provide functions other than cooling. Interlocking controls are used in conjunction with humidistats to control humidity along with temperature. It is possible to increase the complexity of the control system to incorporate almost any type of automatic control desired. The operating control system for each particular system is usually presented verbally and schematically in the applicable operation and maintenance handbook.

Thermostat

A thermostat is a device for the automatic regulation of temperature, utilizing the expansion and contraction of metals or gases caused by the change of temperature. The single pole thermostat controls a cooling system by turning it on and off at adjustable temperatures.

The two-position heating-cooling thermostat controls the operation of the air-conditioning system by selecting heating or cooling. The heating function of air conditioning is discussed later in this chapter. A simple diagram is illustrated by figure 4-15. All of the components are mounted on a bakelite base. When the bimetal element cools, it contracts and moves away from contact R toward contact B. When the bimetal element is heated, it expands and moves toward contact R and away from contact B. When the bimetal element moves toward either contact, the detents, which are two small magnets, attract the element to the contact, rapidly closing the control circuit. This reduces arcing and burning of the contact points. The adjustment lever is set to the desired room temperature. If a warmer temperature is desired,



244.13

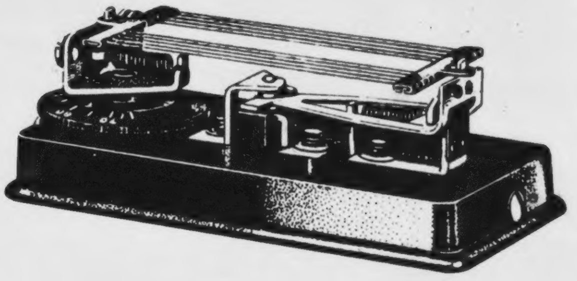
Figure 4-15.—Two-pole heating-cooling thermostat.

the adjustment lever is rotated to the right. The bimetal element in turn moves closer toward contact B. The element would now have less distance to travel in order to turn on the heating system. When the desired temperature is reached, the bimetal element expands and moves away from contact B, opening the heater control circuit.

Common commercial thermostats are sensitive to ±2° F. The location of the thermostat is very important. It should be located where it is exposed to unrestricted, natural air circulation, and for average conditions of the conditioned space. It should not be located near isolated sources of heat or cold (such as lamps, motors, sunlamps, concealed pipes, or ducts within the wall) which may affect the control point temperature.

Humidistat

The humidistat is designed to control either humidifying (adding moisture) or dehumidifying (removing moisture) equipment, or to control both with one instrument.



244.14

Figure 4-16.—Humidistat.

The operating element is composed of approximately 150 strands of human hair (fig. 4-16) (thin strips of balsa wood are used in some units) carefully selected and specially treated. This element is sufficiently sensitive so that the slightest change in humidity will cause the control to function. The control unit is mounted vertically so that dust and other foreign matter do not adhere to the strands of the hair.

The principle of operation is illustrated in figure 4-17. The sensitive element, human hair or wood, stretches when the ambient air humidity increases and contracts as humidity decreases. With the amount of tension on the sensitive element remaining constant, it can be seen that by rotating the humidity selection control, levers A and B (fig. 4-17) will move. Rotating the humidity selection control

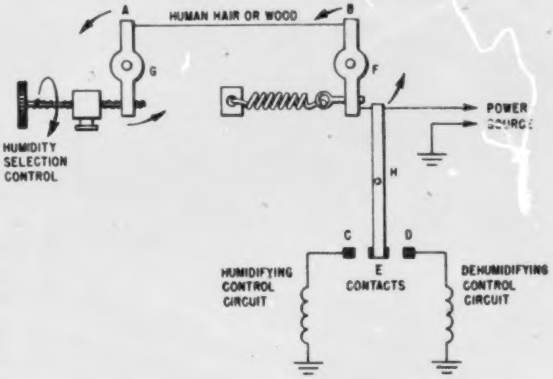

A
HUMAN HAIR OR WOOD
B
G
F
HUMIDITY SELECTION CONTROL
POWER SOURCE
H
C
D
E
CONTACTS
HUMIDIFYING CONTROL CIRCUIT
DEHUMIDIFYING CONTROL CIRCUIT

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Figure 4-17.—Humidistat principles.

clockwise, indicated by the arrow, moves levers A and B counterclockwise around pivots G and F. As lever B rotates counterclockwise, it pushes the top of lever H, moving contact E toward contact C. This action sets the condition for automatic operation. This adjustment is held constant by the spring attached to lever B. A small amount of additional dryness will close contacts C and E, completing the control circuit to add moisture.

If the moisture content of the ambient air increases, the sensitive element will stretch (fig. 4-17). The lever H will rotate counterclockwise, moving contact E toward contact D. When contacts E and D close, the dehumidifying control circuit activates to reduce the moisture content in the spaces.

Condenser Fan Control

A condenser fan control is a device for the automatic control of condenser fans, utilizing the high side system pressure of the compressor to turn the condenser fans on and off at predetermined pressure settings. When the fan is off, the refrigerant in the compressor is hotter and there is a greater volume of gas; consequently, the compressor head pressure increases. High-pressure gas is metered to the bellows in the control unit (fig. 4-18), through a capillary tube. As the head pressure increases, the bellows expand until the switch contacts close. When the contacts close, the circuit to the condenser fan is completed.

With the condenser fan in operation, the compressed gas is cooled by ambient air blowing across the condenser. This action causes the gas to condense to a liquid, and the head pressure is reduced. When the pressure drops below the specified setting, the bellows contract, opening the switch and stopping the fan.

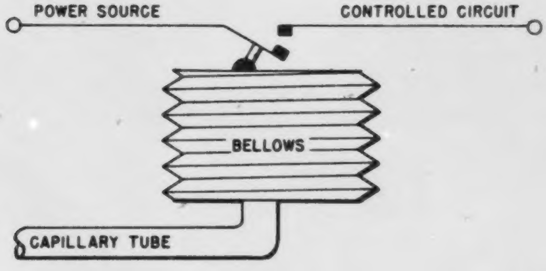

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Figure 4-18.—Condenser fan control.

Circuit Control

The control of the various circuits of a system may vary from simple toggle switches to remote controlled contactor relays. These switches may be used for actuating fans, lights, and motors, or for the checking of various circuits while troubleshooting a defective system. Switches used for maintenance work are called service switches.

A contactor is a type of electrical relay which is used in complex systems where various modes of air conditioning are controlled for one or more refrigeration systems. The contactor has many separate relays mounted on one block. The size of the contacts varies according to the current load of the circuit that is controlled. The movable contacts are moved individually or as a complete group, according to the type of contactor. This allows the control of a single circuit or many circuits simultaneously.

SAFETY CONTROLS

Sufficient safety devices are installed in air-conditioning systems to prevent body injury to operating personnel, damage to the system's equipments, or to the equipment and spaces receiving the conditioned air.

Fusible Plug

The fusible plug is provided to prevent excessive buildup of refrigerant pressures within the confined area of the equipment. The refrigerants commonly used today will act in accordance with the normal liquid/gas laws, whereby increasing the temperature causes increasing pressures. Should the air-conditioning equipment be in close proximity to a fire, a positive method of releasing gas and liquid within the refrigeration system must be provided to prevent the buildup of pressure within the system. The fusible plug is normally located at the inlet connection of the receiver tank. When excessive external heat is present, due to fire or other similar causes, the plug melts, allowing the refrigerant gas to escape from the system. This reduction of gas pressure prevents possible rupture or explosion of the equipment.

Overload Switches

An example of the overload safety switch was described for the compressor and compressor motor. When failures occur within the equipment, the overload switch opens the circuits supplying power to the equipment.

Thermal Cutout

This safety control is used in installations that provide electric heaters for the heating of the conditioned spaces. The thermal cutout has an adjustment whereby a predetermined temperature can be set. If the temperature rises above the setting, the thermal cutout opens the circuit to the electric heaters. This safety device protects the units located near the heaters from abnormally high temperatures.

High- and Low-Pressure Cutouts

The high- and low-pressure cutout switches are incorporated in the refrigeration cycle to control the operation of the compressor. The pressure control prevents the discharge pressure of the compressor from building up beyond a reasonable limit. This control contains an electric switch and a bellows (fig. 4-18) which, through appropriate linkage, open and close the motor circuit of the compressor.

The basic operation is similar to that shown in figure 4-18 with the addition of a method for adjusting the desired cutout pressures. (See fig. 4-19.) A capillary tube transmits the pressure from the high side of the refrigeration system to the bellows. Should the compressor head pressure increase above the predetermined setting of the control, the pressure opens the switch contacts and stops the compressor.

The control unit illustrated in figure 4-19 contains controls for both the high- and low-pressure gases. In some installations the high- and low-pressure controls are mounted in separate units; however, their operation is essentially the same as described herein.

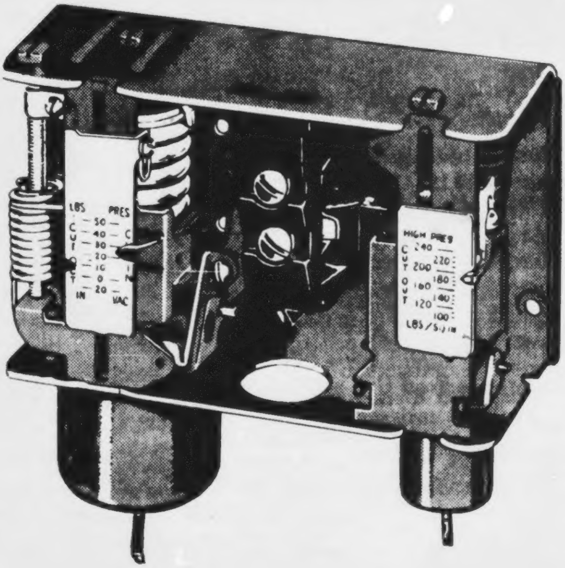

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Figure 4-19.—High- and low-pressure cutout.

The low-pressure cutout operates the same as the high-pressure unit, except the capillary tube transmits the pressure present in the suction side of the refrigeration system to the bellows. If the suction pressure decreases too low (at or near atmospheric pressure), the bellows will operate the switch to stop the compressor. If the suction pressure falls below atmospheric pressure, outside air can leak into the refrigeration system. The atmosphere contains water vapor; and if any portion of the refrigeration system is below atmospheric pressure and a leak exists in any portion of the system, air entering the system through a leak would be detrimental to the interior workings of the system.

MAINTENANCE

To ensure the efficient operation of air-conditioning equipment, a program of preventive and corrective maintenance is very

Table 4-1.—Preventive maintenance checklist

Description	Interval
1. When a unit is equipped with a humidifier and is being used for heating and humidifying, check the water level in the reservoir and fill if needed.	DAILY
2. Remove air filters and clean (at least one complete set of extra filters should be available for each unit).	WEEKLY or every 100 hours of operation
3. Check air circulating fan belt for tightness. (When "squeezing" the belt between forefinger and thumb, the belt should not move more than 1 inch. If the belt moves more than 1 inch, then slippage will occur, causing inoperation of the unit. Excessive tightness results in bearing or belt failure and may overload the motor.)	WEEKLY
4. Check the refrigerant sight glass of each stage for indication of a low refrigerant charge. If a low charge is indicated, locate and repair the leak and recharge the system. A low charge is indicated by bubbles or a milky appearance in the sight glass.	WEEKLY
5. Inspect the evaporator coils for cleanliness. If dirty, brush with a long bristle brush and remove dirt with a vacuum cleaner.	WEEKLY
6. Inspect the condenser coils for cleanliness. If dirty, proceed as in item 5.	MONTHLY
7. When the unit is equipped with a humidifier, check the humidifier for operation and lubricate. Use a light oil.	2 MONTHS
8. With a clean dry cloth, wipe off the drier filter, solenoid valves, sight glasses, heat exchanger, and the thermostatic expansion valve. Check the tightness and general condition of each component as it is cleaned.	2 MONTHS
9. Check the heaters to be sure that wires and heater mounting bolts are tight. Be sure heater fins are clean, not bent, and that no wires are touching the heaters.	2 MONTHS
10. Check the mounting bolts and setscrews for tightness on condenser and air circulating fans, fan shafts, and motor shafts. Check the blower wheel and fan scroll clearances.	2 MONTHS
11. Wipe off the compressor with clean dry cloths; look for and make repairs to the following: a. Loose bolts. b. Loose capillary connections. c. Frayed or broken wires. d. Loose valve caps and gage port plugs. e. Oil leaks beneath compressor and around gaskets.	2 MONTHS

Table 4-1.–Preventive maintenance checklist–Continued

Description	Interval
12. MAKE SURE ALL OPEN VALVES ARE BACK SEATED.	
13. Check each stage for refrigerant leaks using a halide torch or other precision leak detector. Check items such as flare nuts, welded connections, bolted connections, all types of fittings, valves, pack nuts, coil manifolds, and return bends. Check any place where oil has been found for refrigerant leaks; repair any leaks found.	2 MONTHS
14. Check the electrical system completely for cleanliness, loose terminals, loose connections, loose mounting bolts or screws, frayed wires, and loose components. Also check contactors for normal opening and closing.	2 MONTHS
15. Check all pressure switches for correct settings and tightness of mounting brackets. Refer to the maintenance manual.	2 MONTHS
16. Check overflow pipes in reservoir and drain pans and clean out any dirt or sediment.	
17. Check all clamps, mounting brackets, and the tightness of all components.	2 MONTHS
18. Inspect all air inlet and outlet openings for obstructions.	2 MONTHS
19. On all units where applicable, lubricate circulating fan motors and condenser fan motors and all other parts as required.	2 MONTHS
20. Be sure all access panels and cabinet panels are securely tightened in place to prevent air leaks.	2 MONTHS

important. The procedures for a particular system, as set forth in the manufacturer's maintenance manuals, should be closely followed. These procedures differ from one system to another. The information provided in this section is general in coverage to provide the TD with an overall view of the maintenance problems of air-conditioning systems; it should not be used in place of the manufacturer's maintenance manual.

PREVENTIVE

Preventive maintenance is better than waiting for an adverse condition to develop, and then having to correct it. This helps to prevent loss of training time and reduces the cost of materials. The important factors in the maintenance of an air-conditioning system are the same three factors that should be observed in the use of all mechanical equipment: cleanliness, lubrication, and periodic inspection.

Table 4-1 sets forth a suggested preventive maintenance program.

NOTE: Item 13 of table 4-1 is very important because all oil leaks found in the area of the compressor denote excessive leakage of the refrigerant. The refrigerant is present with the oil in the crankcase of the compressor, and any leakage of this oil is a leakage of the refrigerant.

CAUTION: When there is a very serious refrigerant leak, the concentration of the halogen gas being burned in the acetylene mixture is high, and this results in a deep purple, lazy flame of the leak detector. This lazy purple flame is producing phosgene gas, a deadly poison with the odor of new cut hay. Do not use a torch in a confined area and do not breathe the gas coming off a lazy purple flame of a leak detector. Just as soon as a purple flame occurs, withdraw the test probe. Make certain there is plenty of circulating air to blow this gas out of the confined space. Then use the torch to locate the leak. Repair the leak as necessary. Electronic leak detectors that provide a safer method of detecting refrigerant leaks, and with increased sensitivity, are available.

As stated in table 4-1, cleaning is best accomplished by using a vacuum cleaner or soft hairbrush. The ventilating fins on the condenser and evaporator are made of thin metal and bend easily. Extreme care should be taken not to bend the fins, as bent fins obstruct the passage of air.

Maintenance and overhaul on motors should be performed in accordance with the instructions contained in the manufacturer's maintenance manual.

When placing new equipment into operation, and even when starting up a system that has been out of operation for a period of time, you should give the entire system a checkover. Use a straightedge to ensure that the compressor and motor pulleys are in line. Check the belt tension. Remember that if there are two or more V-belts on one drive, they must have identical tension; otherwise, one will carry more than its share of the load, overheat, and wear out. When one V-belt of a multiple set must be replaced, change the whole set, in order to ensure uniformity of length and tension.

Refer to the manufacturer's maintenance manual for various setup and inspection procedures.

CORRECTIVE

Faulty operation of any air-conditioning system is indicated by definite symptoms. The symptoms differ according to air- and water-cooled systems. These symptoms may be caused by one or more incorrect conditions which must be eliminated in a step-by-step process of corrective measures. The trouble symptoms, causes, and corrections, included in table 4-2, are general in coverage to present examples of possible troubles. However, the manufacturer's maintenance manual contains troubles and remedies as applied to the specific system and should be used when maintaining the equipment.

Quiet operation of air-conditioning systems is not only desirable but is very important where training spaces are concerned. To test for excessive noise, operate the system at maximum load. Then listen, both outdoors and indoors, for noisy operation of the equipment.

Locate the noise sources in respect to parts of the equipment, and try to analyze them. A frequent cause of operating noise, for example, is an unbalanced fan. Loose belts, faulty motor bearings, or misalignment of components can result in noisy operation of the unit. The defects, if neglected, may become a major repair problem.

In correcting defects, however, personnel should not tamper with such components as hermetically sealed refrigeration equipment, or factory calibrated automatic controls. Refer to the maintenance manual for the scope of field maintenance. If the repair of the system cannot be accomplished by authorized adjustments or repairs, assistance should be requested in accordance with instructions contained in *Training Equipment Guide*, NAVTRADEV P-530-2.

Repair Equipment

Small tools required for repair operations are hammers, hacksaws, tube and wire cutters, piping tools, wrenches, pliers, screwdrivers, files, and hand levels. Also needed is such equipment as a halide torch, gas torch, pressure gages, and a refrigerant charging assembly. (See fig. 4-20.) Many air-conditioning manufacturers furnish a set of special tools for maintaining the specific system of equipments.

Service gages come in the form of a gage manifold with the necessary valves and connections. The pressure gage is on one side, and the compound gage on the other. (See fig. 4-21.) The gages are mounted on a manifold

Table 4-2.—Trouble diagnosis chart—air-cooled condenser

Symptom or difficulty	Condition may be due to	Correction
High head pressure	Airflow to condenser restricted.	Remove loose articles that would tend to restrict the flow of air.
	Air or noncondensable gas in system.	Purge air from system.
	Overcharge of refrigerant.	Draw off refrigerant into service drum.
Low head pressure	Leaky suction or discharge valve.	Test with gage; if leaking, replace.
	Shortage of refrigerant.	Add refrigerant.
Low suction pressure	Restricted liquid line, expansion valve screen, or suction screens	Pump down, remove, examine, and clean screens.
	Insufficient gas in system.	Check for gas shortage.
	Too much oil circulating in system.	Check for too much oil in circulation. Remove oil.
	Improper adjustment of expansion valves.	Adjust valve to allow more flow.
	Stuck or frozen expansion valve.	Tap or thaw expansion valve as necessary.
High suction pressure	Overfeeding of expansion valve.	Regulate expansion valve; check thermal bulb attachment.
	Leaky suction or discharge valves.	Test with gages; if leaking, replace.
Compressor is intermittent during high pressure cutout.	Insufficient air flowing through condenser.	Remove any debris that would block the airflow.
	High pressure cutout incorrectly set.	Check setting of high pressure cutout.
	System overcharged with refrigerant. High pressure cutout tripping due to insufficient condenser capacity.	Draw off refrigerant into service drum.
	Air or noncondensable gases in system.	Purge air from condenser.
Compressor is intermittent during low pressure cutout.	Coils in refrigerators clogged with frost. Suction or expansion valve screens clogged.	Pump down and clean screens.
	Thermal bulb on expansion valve has lost charge.	Detach thermal bulb from suction line and hold in palm of hand, gripping the suction line with the other hand. If flooding through is observed, bulb has not lost its charge. If no flooding through is observed, replace expansion valve.
Compressor runs continuously.	Shortage of refrigerant.	Test for leaks. Add refrigerant.
	Suction or discharge valves leak badly.	Test valves. If necessary, repair or replace.
	Head gasket blown between cylinders.	Replace gasket.
	Liquid, suction or expansion valve screen clogged. (With temperature control.)	Pump down and clean screens.
	Improper control settings, stuck electrical contacts.	Readjust control settings, clean and adjust contacts.

Table 4-2.—Trouble diagnosis chart—air-cooled condenser—Continued

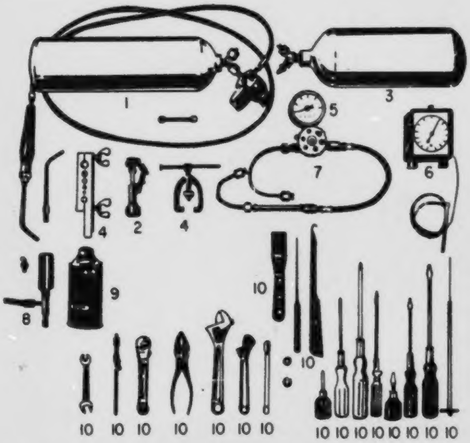
Symptom or difficulty	Condition may be due to	Correction
Compressor noisy.	Vibration; not bolted to foundation rigidly.	Bolt down rigidly.
	Too much oil in circulation causing hydraulic knock.	Check oil level.
	Wear of parts such as piston pins, eccentrics, etc.	Determine location of cause. Repair or replace compressor.
	Excessive high head pressure.	Check reason for high head pressure and correct.
	Lack of lubricating oil.	Check oil level and add as required.
Oil does not return to crankcase.	Valve in oil return line closed or stuck shut.	Open.
Compressor will not start.	Overload tripped, fuses blown.	Reset overload, replace fuses, and examine for cause.
	No charge of refrigerant in system operated by a low-pressure control switch.	Recharge.
	Solenoid valve on liquid line closed.	Replace or repair.
	No voltage or low voltage.	Check for voltage.
Oil leaves crankcase.	Leaky piston rings or worn cylinders.	Replace rings or compressor, or rebore and refit.
	On starting, suction pressure drops too rapidly.	Run the compressor intermittently.
Cylinders and crankcase sweating.	Too much oil in circulation.	Examine for conditions of refrigerant and correct the condition.
	Liquid refrigerant returning to compressor.	
Crankcase frosting	Liquid refrigerant returning to compressor.	Adjust expansion valve.
Head gasket leaks	Head bolts stretched or washers crushed.	Examine gasket; replace if necessary. Tighten head bolts. Replace washers. (NOTE: Head bolts are generally tightened with a torque wrench.)

which has three line connections and two shutoff valves that separate the gage openings from the centerline connection. This manifold enables the repairman to connect his gages to the system and allows him to charge and discharge a system, check the pressures, add oil, and any other required operations.

As shown in figure 4-21, the manifold gage (A) is connected by a flexible charging line to the suction side (D) of the compressor. The pressure gage (B) is connected to the discharge side (C) of the compressor. The manipulation of the manifold shutoff valves for the various operations is illustrated in figure 4-22.

To install the gages shown in figure 4-21, proceed as follows:

1. Remove the cap of the compressor suction service valve, and turn the valve stem outward as far as it will go to its back seat. This



1. Presto-lite torch.
2. Tube cutter.
3. Gas tank.
4. Flaring tool—anvil and split bar.
5. Pressure gage.
6. Thermometer.
7. Set of fittings.
8. Halide torch.
9. Can of refrigerant oil.
10. Miscellaneous handtools.

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Figure 4-20.—A typical set of tools needed for servicing air conditioners.

closes off the service gage port from the compressor crankcase and suction line.

2. Remove the plug from the gage port, and replace it with a flared tube connector fitting.

3. Connect the flared tube fitting with the flexible tube on the 30-inch vacuum, 150-lb compound gage side of the manifold.

4. Move the valve stem of the suction service valve inward, off the back seat, about one-half turn, and tighten the gland nut.

5. Crack the valve on the compound gage side of the manifold to allow air in the flexible line to escape through the service drum connection.

6. Repeat the same procedures to connect the pressure gage side of the gage manifold to the service port of the DISCHARGE service valve.

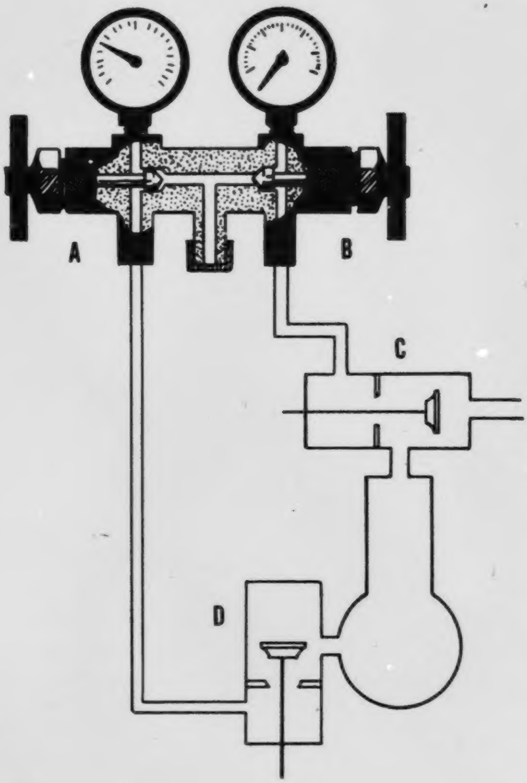

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Figure 4-21.—A manifold service gage.

To open the condenser service valve (if installed), remove the valve cap, and then turn the valve stem outward 8 or 10 turns, or until it back seats. Tighten the gland nut and replace the valve cap, pulling it up until it just compresses the gasket. Next, slightly open the compressor discharge service valve. Never start a compressor with the discharge service valve closed.

Open the receiver stop (or king) valve by removing the cap and cracking the valve until the compound gage reads 50 psi. Then close the valve and tighten the gland nut.

Reading Pressures

High and low side pressures are a good indication of how the system is functioning. A

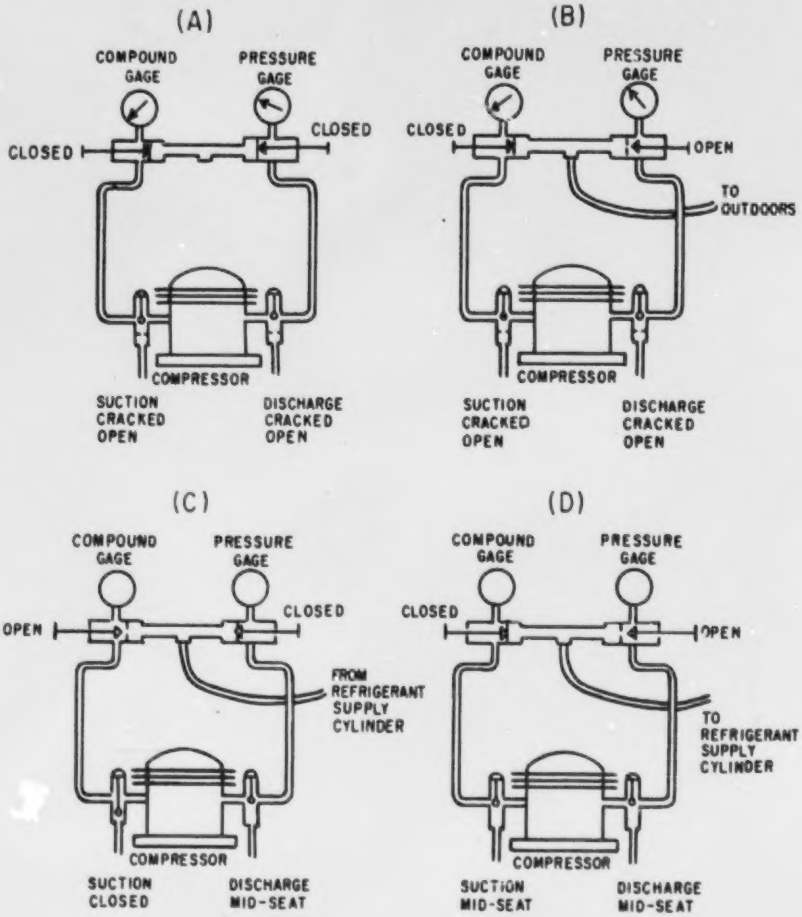

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Figure 4-22.—Service valve connections. (A) Reading pressure; (B) purging the system; (C) charging to low side; (D) charging to high side.

comparison can be made of the readings as against the prescribed readings in the manufacturer's maintenance manual.

The manifold gage is set up as shown in figure 4-22 (A). Note the positions of the three-way suction and discharge service valves. Pressures may be read while the compressor is idle or running.

When reading pressure or adding refrigerant, always be sure to purge (bleed) the tubing line or lines first. This is done by leaving the connections loose at one end of the tubing (at the service valve end for adding; at the manifold gage end for reading pressures) and admitting some refrigerant into the lines. Next, tighten all connections and set the valves in the appropriate positions as shown in figure 4-22 (A). Air and moisture normally present in the tubing are admitted into the sealed system if purging is not done.

Bleeding the System

Any air or moisture in a system must be removed. The presence of air is indicated by pressure and temperature readings that will vary from the prescribed readings in the maintenance manual. The air in the system mixes with the refrigerant vapor, but does not mix with the refrigerant liquid. To remove air from the system, it is only necessary to remove the refrigerant vapor. This is accomplished by bleeding (purging) the low side of the compressor with the gages installed and valves set as indicated in figure 4-22 (B). The procedure is:

1. Set the manifold gage valves so the compound valve is closed and the pressure valve is open.
2. Start the compressor and crack both the suction and discharge service valves.
3. Observe that the pressure gage needle begins to drop as the refrigerant vapor is expelled.
4. When the pressure reaches the prescribed level, turn the suction and discharge service valves to their normal operating positions.

Evacuating and drying the unit is an important part of all assembly work. As nearly as possible, the system should be clear of air, moisture, and other foreign matter. The general steps for evacuating and drying a unit are:

1. Evacuate.
2. Charge with CO_2 to the prescribed pressure and heat as directed.
3. Evacuate and check for moisture. If moisture is present, repeat steps 2 and 3.
4. Charge with refrigerant gas and heat as prescribed.
5. Evacuate.
6. Charge with refrigerant to the prescribed level.

The most careful evacuating and purging will not clean a dirty unit that was carelessly put together. A good vacuum pump should be used to remove as much air as possible from the unit. A rotary pump produces the best vacuum in most cases. However, the best pumps will not remove all the air. A pump that produces a 28-inch vacuum is only removing 28/30 of the air or 93 percent. In a 28-inch vacuum, moisture must be heated to 100° F to be vaporized and thus be pumped out as water vapor.

To remove moisture efficiently, the unit must be heated to a temperature that vaporizes the moisture in the little cracks and crevices that exist throughout the system. The unit may be operated for part of this operation to ensure that all pockets in the compressor, motor windings, and bearings are agitated to release trapped air. Duration and temperature of evacuation are prescribed in the maintenance manual for the equipment involved.

Carbon dioxide has an affinity for moisture, and circulating it in the system helps to remove moisture. Charging with refrigerant gas and again evacuating reduce the amount of air to about 0.8 percent of the air originally in the system. The remaining air may be removed by purging the condenser after the system has been in operation for a short time.

Where available, a moisture indicator should be used to determine that the system is free of moisture before the refrigerant is introduced into the system.

Adding Refrigerant Vapor to the Low Side

Refrigerant is available in large tanks and small disposable cans. The small disposable can is convenient for adding small quantities of refrigerant. A suggested procedure is:

1. Connect the gages and service valves as shown in figure 4-22 (C).
2. Set the valves as indicated in figure 4-22 (C). The suction service valve is closed, allowing the incoming vapor to enter the compressor.
3. Hold the refrigerant tank or can below the level of the inlet to the compressor. This allows the vapor to enter the system rather than the refrigerant liquid.
4. Start the compressor.
5. When the prescribed suction and discharge pressures are reached, stop the compressor.
6. Place the service valves in their normal operating positions and disconnect the gage set and tubing lines.

Adding Liquid Refrigerant to the High Side

This procedure differs from the foregoing by adding liquid rather than vapor. The suggested procedure is:

1. Set the manifold gage valves and gages as shown in figure 4-22 (D).

2. Purge the connecting lines.

3. Hold the refrigerant supply can higher than the inlet valve and pointed downward. With the can upside down, the liquid flows out of the can rather than vapor. Although it is not usually a recommended procedure, some servicemen do put liquid refrigerant into the high pressure side of the system. This is a dangerous practice because dynamic hydraulic pressures are possible which may rupture the lines and cause considerable damage. However, this method can be used to put the initial charge into a system if done carefully.

4. The compressor must have been idle long enough for the pressure in the liquid line to drop and the temperature of the line lowered to approximately the ambient temperature.

5. Gravity will allow the liquid refrigerant to flow down through the tubing line into the liquid line of the system. To accomplish this, the pressure must be greater in the supply can than in the system.

6. Continue adding refrigerant until the liquid sight glass is clear. If the sight glass appears milky or has bubbles in it, the system does not have a full charge.

7. When the prescribed amount of refrigerant has been added, place the service valves in their normal operating positions and disconnect the gage set and tubing lines.

Testing for Leaks

Small leaks in a system cannot be located without utilizing a sophisticated electronic leak detector, unless the pressure inside the system is from 40 to 50 psi. There is always sufficient pressure in the high pressure side of the system, but on the low side, pressures are sometimes only slightly above zero psig. To test for leaks, therefore, you must increase pressures on the suction side by bypassing discharge pressure from the condenser to the suction side, through the service gage manifold, when the compressor is shut down.

If you are going to test for leaks in a system, be sure the working space is well ventilated before you light off the torch. Remember, this gas, from the torch, is highly flammable.

The halide torch, illustrated as item 8 in figure 4-20, is the most common device for testing for leaks in Refrigerant-12 systems. Keep the flame of the torch as low as possible, so that even a small refrigerant leak will cause the flame to change color. The torch should show a blue flame when lighted, and this changes to a greenish flame when it contacts a refrigerant leak. If it burns with a greenish flame when lighted, there is refrigerant in the air. Go over all joints, especially flared tube nuts, fittings, sweat connections, and gasketed joints.

A soap and water solution can be used to test any system. It can be applied with a soft brush; but, you must wait until all bubbles have disappeared from the solution. Then, if bubbles appear after it has been brushed on to the joints or tubing where leakage is suspected, they are caused by the escaping refrigerant.

Copper Tubing

The tubing used in all air-conditioning systems is specially annealed copper tubing. The purpose of the annealing is to make the copper flexible and to adapt the tubing for flaring and bonding. Tubing may be obtained in sizes from 1/4-inch to 3/4-inch in outside diameter. When ordering tubing, be sure that dehydrated, annealed, and seamless tubing is specified.

A hacksaw with fine teeth can be used for cutting tubing; however, the tube cutter illustrated as item 2 in figure 4-20 is recommended.

One method of connecting tubing uses flares and flare nuts. (See fig. 4-23.) A special tool is available for the making of the flare and is illustrated as item 4 in figure 4-20. The split flared block contains several holes for different sizes of tubing. The anvil tool has a chamfered

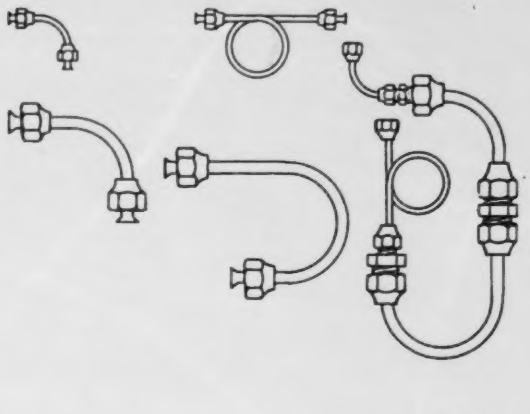

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Figure 4-23.—Copper tube flares, flare nuts, and bends.

tip which is tightened into the tubing and opens the walls of the tubing into a flare. (See fig. 4-23.)

The bending of copper tubing is very important to the successful operation of the line. The tubing must be carefully bent as illustrated in figure 4-23. A special bending tool is available and must be used for bending large sizes of tubing. The smaller sizes of tubing used in air conditioners can be bent by hand. However, a neater job is accomplished by using a bending tool. The main concern is that the tubing be bent so that it does not apply any strain on the fittings and that the tubing wall is not crimped or collapsed by the bend. The recommended minimum radius to which tubing may be bent is between five and ten times the diameter of the tubing.

Another method of connecting copper tubing is soldering. (See fig. 4-24.)

The sequence of steps for soldering as illustrated in figure 4-24 is:

1. Cut tubing to proper length. Remove the burr from the inside and outside of the tubing with a file or scraper.

2. Clean the outside surface of the tubing with sandpaper.

3. Clean the inside surface of the tubing with a wire brush, sandpaper, or sandcloth.

4. Apply flux to the inside surface of the fitting. The most satisfactory flux to use is made of alcohol and rosin. When acid flux is used, it tends to corrode the fittings and makes them unsightly.

5. Apply flux to the tubing ends and fittings.

6. Apply heat with a torch. (See item 1 of fig. 4-20.) When the solder melts upon contact with the heated fitting, the proper temperature for soldering has been reached. Remove the flame and feed the solder to the joint at one or two points until a ring of solder appears at the end of the fitting.

Safety Precautions

In general, the safety precautions to observe with regard to the refrigerant in an air-conditioning system are as follows:

1. Never mix different refrigerants in the same system. This rule applies to Refrigerant-12 and Refrigerant-22; a system designed for Refrigerant-12 requires redesigning if Refrigerant-22, or any other Freon type refrigerant, is to be substituted.

2. Do not fill a refrigeration system until the piping has been evacuated, cleaned, and dried free of moisture. Watch your moisture-indicating devices to see if the refrigerant has become contaminated with moisture.

3. Never operate the air-conditioning system when the refrigerant supply in the system is very low. The first result would be that a layer of insulating frost would cover the evaporator and no cooling would result. Then, because of nonstop operation of the unit, motor failure and damage to the compressor could occur.

4. Do not allow any part of a refrigeration system to become overheated.

5. Never use a torch around a system that operates with an explosive refrigerant.

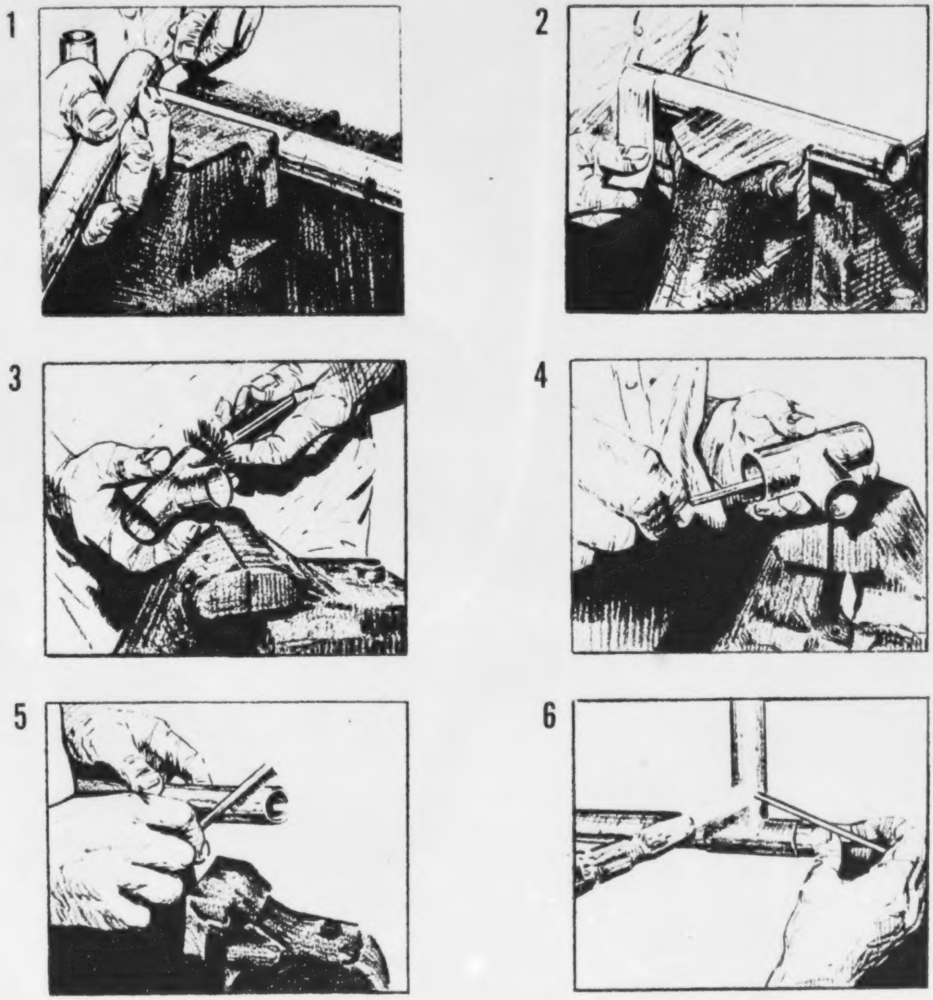

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Figure 4-24.—Steps for soldering copper tubing.

6. When the refrigerant must be drawn out of a system into a cylinder, remember that 85 percent full is the maximum safe capacity of a gas cylinder.

7. In charging a system, keep a close watch upon gages to avoid overcharging.

8. When you loosen a connection in which Refrigerant-12 is confined, wear goggles to protect your eyes. If Refrigerant-12 does come in contact with your eyes, use sterile mineral oil or olive oil as a soothing application. DO NOT RUB YOUR EYES. If possible, report at once to the medical officer.

9. If Refrigerant-12 comes in contact with your skin, treat it as you would a frostbite.

10. Any person who is overcome in a space that lacks the necessary oxygen because of a high concentration of Refrigerant-12 must be moved to a fresh airspace, and then given artificial respiration.

11. Turn off all power to prevent the automatic starting controls from starting the system which might result in injury to personnel. Refer to the service manual.

12. Always operate the compressor with the service valve in the open position to prevent possible physical damage to the compressor and personnel.

13. Release pressure from the system before brazing or soldering.

14. Never permit liquid to enter the low side of the compressor; liquid in the compressor will cause damage.

CHAPTER 5

SIMULATOR MOTION SYSTEMS

As with most chapters in an advanced rate training manual, the information presented in this chapter builds upon information contained in a basic or "blue" book, namely *Fluid Power*, NAVPERS 16193 (Series). Even though the first part of this chapter provides a brief review of the components and operation of a basic hydraulic system, you may want (or need) the more in-depth study of the basics provided by the manual named above.

After an introduction to a basic fluid power system, a two-degree-of-freedom motion system is described, using Device 21C5 as an example. This is followed by a discussion of a more sophisticated and complex motion system utilized by Device 2F101, the six-degree-of-freedom motion system.

COMPONENTS OF A BASIC SYSTEM

The basic components of a fluid power system are essentially the same, regardless of whether the system employs a hydraulic or a pneumatic medium. There are five basic components used in a system:

1. Reservoir or receiver
2. Pump or compressor
3. Lines, (pipe, tubing, or flexible hose)
4. Directional control valve
5. Actuating device

The term RESERVOIR is associated with hydraulic systems, and the term RECEIVER with pneumatic systems. The primary purpose of a reservoir or receiver is to provide a storage space for fluid used in the respective systems. The two components, however, differ in some respects. In the case of the receiver, a volume of fluid (gas) is stored under pressure and is supplied to the pneumatic system as needed to operate the system. The pressure of the gas provides the flow and force required to operate the system. After the gas is used for an operation, it is exhausted to the atmosphere and a new supply of fluid is compressed in the receiver. In converse, the fluid in most hydraulic reservoirs is not pressurized. Although some hydraulic reservoirs are pressurized, this pressure does not supply the force to operate the system but is limited to the amount necessary to ensure a supply of fluid to the hydraulic pump at all times. In addition, the fluid of a hydraulic system is used over and over again, flowing from the reservoir to the other components, back to the reservoir, to the components, etc. Therefore, a well designed reservoir also serves as a heat exchanger to control the temperature of the fluid, and as a place to filter and clean the fluid. Reservoirs and receivers are discussed in detail in chapter 7 of *Fluid Power*, NAVPERS 16193-B.

A fluid power system requires a power unit to convert mechanical energy into fluid energy. In pneumatic systems, this unit is referred to as a COMPRESSOR, while in hydraulic systems, this unit is called a PUMP. Like the reservoirs and receivers discussed in the preceding paragraph, the pump and compressor differ in some respects. These differences and detailed information concerning the types and operation of pumps and compressors are covered in chapter 8 of *Fluid Power*. Basically, the compressor, which is driven by some outside power source, compresses the fluid (gas) in the receiver. The hydraulic pump, also driven by an outside power source, provides a flow of fluid to a hydraulic system.

The LINES are the medium for transmitting the fluid from one component to another. This is normally accomplished by using pipe, tubing, or flexible hose for interconnecting reservoirs to pumps, pumps to valves, valves to cylinders, etc. The different types of fluid lines and connectors are covered in chapter 5 of *Fluid Power.*

The DIRECTIONAL CONTROL VALVE (also referred to as a selector valve) is a device which directs a flow of fluid to and from the actuating device. Some of the most common types of directional control valves and their applications are described and illustrated in chapter 11 of *Fluid Power.*

The ACTUATING DEVICE of a fluid power system is that component which converts the fluid pressure into useful work. Actuators perform the opposite function of hydraulic pumps and pneumatic compressors in that they convert fluid energy into mechanical energy. Common types of actuating devices are the cylinder, which provides linear motion, and motors, which provide rotary motion. The types and operation of actuating devices are covered in chapter 12 of *Fluid Power.*

These five basic components, when combined into one unit, are the basis for a fluid power system. An example of a basic hydraulic system is illustrated in figure 5-1.

The flow of fluid can be traced readily from the reservoir, through the pump, to the directional control valve. With the control valve in the UP position, as shown, the flow of fluid provided by the pump flows through the valve to the right-hand end of the actuating cylinder. Fluid pressure then forces the piston to the left and, at the same time, the fluid on the left side of the piston is forced out of the cylinder, through the control valve, and back to the reservoir through the return line.

When the control valve is moved to the DOWN position, as shown in the insert of figure 5-1, the fluid flows from the pump through the control valve, to the left side of the actuating cylinder, thus reversing the process. Movement of the piston can be stopped at any time simply by moving the control valve to neutral. In this position, all four ports are closed and pressurized fluid is trapped in both working lines.

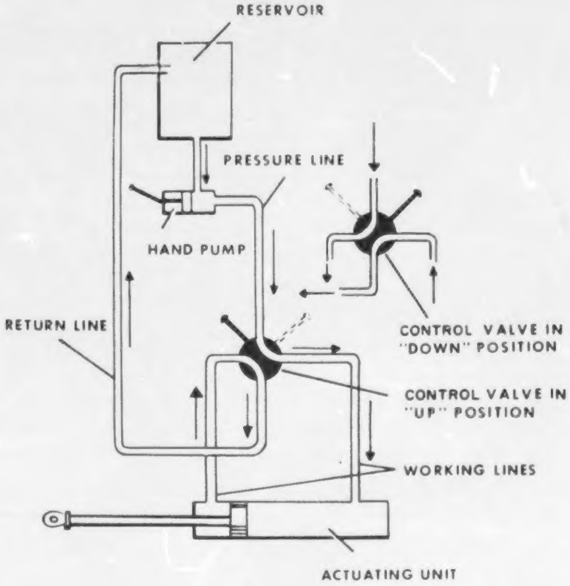

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Figure 5-1.—Basic hydraulic system, hand pump operated.

The example shown in figure 5-1 could very well represent a basic pneumatic system by replacing the reservoir with a receiver and the pump with a compressor and reversing their positions in the system. Thus, the fluid would flow from the compressor into the receiver and from the receiver to the control valve. The return fluid from the actuating cylinder is exhausted from the control valve; therefore, the return line, as shown in figure 5-1, is not required in a pneumatic system.

This basic system is one from which any system can be derived. The hand pump may be replaced with a power pump and the actuating device may be a motor. Additions may be added for the purposes of providing additional sources of power, operating additional cylinders, making operation more automatic, or increasing reliability. However, these additions are all made on the framework of the basic system.

With the addition of a few components, a basic system can be improved into a more workable system. Figure 5-2 shows a basic system with the addition of a power-driven pump and the following essential components: filter, pressure regulator, accumulator, pressure gauge, relief valve, and two check valves. The functions of each of these components are briefly explained in the following paragraphs. The types, construction, and operating features of these components are described in detail in *Fluid Power*, NAVPERS 16193-B.

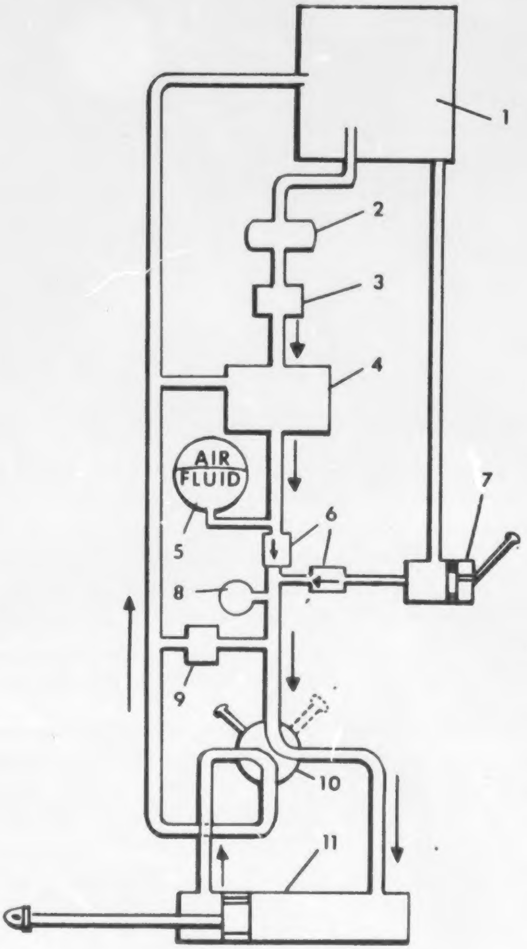
The FILTER removes foreign particles from the fluid, preventing dust, grit, and other undesirable matter from entering the system.

The purpose of the PRESSURE REGULATOR is to unload or relieve the power-driven pump when the desired pressure in the system is reached. It is therefore often referred to as an unloading valve. When the pressure in the system builds up to the desired point, a valve in the pressure regulator opens and fluid from the pump is bypassed back to the reservoir. The bypass line is shown in figure 5-2 leading from the regulator to the reservoir. At the same time, the pressure in the remainder of the system is maintained at the desired pressure. When this pressure drops, due to the operation of an actuating unit or internal or external leakage, the valve in the regulator closes, allowing the pressure in the system to build up to the desired amount.

Many fluid power systems do not use a pressure regulator, but have other means of unloading the pump and maintaining system pressure. Such methods are described in *Fluid Power*, NAVPERS 16193-B.

The ACCUMULATOR serves several purposes in a hydraulic system. It serves as a cushion or shock absorber by absorbing pressure surges in the system, and it stores enough fluid under pressure to provide for emergency operation of certain actuating units. It is designed with a compressed-air (or nitrogen) chamber separated from the hydraulic fluid by a flexible diaphragm, synthetic rubber bladder, or movable piston.

The PRESSURE GAUGE indicates the amount of pressure in the system.



1. Reservoir
2. Power pump
3. Filter
4. Pressure regulator
5. Accumulator
6. Check valves
7. Hand pump
8. Pressure gage
9. Relief valve
10. Control valve
11. Actuating device

194.37

Figure 5-2.—Basic system with addition of power pump and other components.

The RELIEF VALVE is a safety valve installed in the system so that fluid is bypassed through the valve and back to the reservoir in case excessive pressure is built up in the system.

CHECK VALVES allow the flow of fluid in one direction only. There are numerous check valves installed at various points in most fluid power systems. A careful study of figure 5-2 will reveal why the two check valves are necessary in the system. (The arrow on each check valve points toward the direction of free flow.) One check valve prevents power-pump pressure from entering the hand pump line; the other prevents hand-pump pressure from being directed to the accumulator. In a system of this type, the power pump is used in the normal operation of the system. The hand pump serves as an emergency means of operating the system in case of power pump failure. The hand pump may also be used as a means for checking and troubleshooting many of the components of the system.

In the system described in the preceding paragraphs, the fluid in the system from the pump (or regulator) to the directional control valve is under pressure when the pump is operating. Any number of subsystems may be incorporated in such a system with a separate directional control valve for each subsystem. The directional control valves are arranged in parallel whereby system pressure acts equally on all control valves. This type system is referred to as a closed-center system.

Another type of system which is sometimes used in hydraulically operated equipment is the open-center system. (See figure 5-3.) An open-center system is one having fluid flow, but no pressure in the system when the actuating mechanisms are idle. The pump circulates the fluid from the reservoir, through the directional control valves, and back to the reservoir. (See fig. 5-3 (A).) Like the closed-center system, the open-center system may employ any number of subsystems with a directional control valve for each subsystem. Unlike the closed-center system, the directional control valves of an open-center system are always connected in series with each other, an arrangement whereby the system pressure line goes through each directional control valve. Fluid is always allowed free passage through each control valve and back to the reservoir until one of the control valves is positioned to operate a mechanism.

When one of the directional control valves is positioned to operate an actuating device, as shown in view (B) of figure 5-3, fluid is directed from the pump through one of the working lines to the actuator. With the control valve in this position, the flow of fluid through the valve to the reservoir is blocked. Thus, the pressure of the fluid builds up in the system to overcome the resistance and moves the piston of the actuating cylinder. The fluid from the other end of the actuator returns to the control valve through the opposite working line and flows back to the reservoir.

Several different types of directional control valves are used in conjunction with the open-center system. One type is the manually

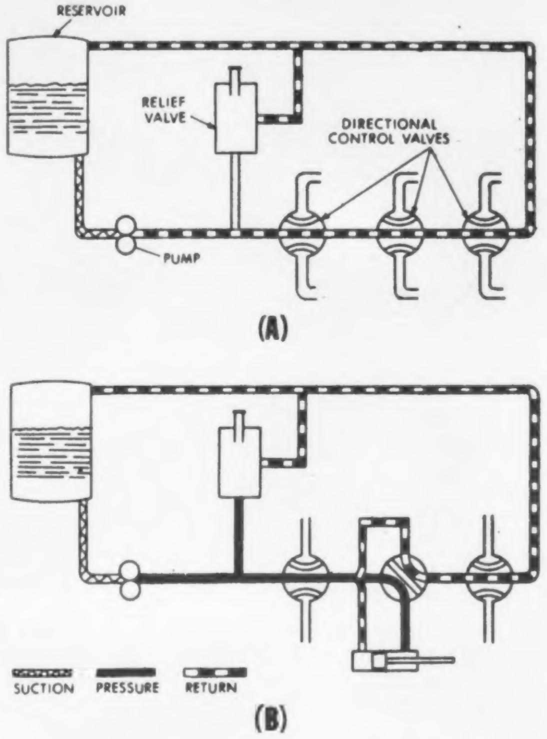


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Figure 5-3.—Basic open-center hydraulic system.

engaged and manually disengaged. After this type valve is manually moved to an operating position and the actuating mechanism reaches the end of its operating cycle, pump output continues until the system relief valve setting is reached. The relief valve then unseats and allows the fluid to flow back to the reservoir. The system pressure remains at the pressure setting of the relief valve until the directional control valve is manually returned to the neutral position. This action reopens the open-center flow and allows the system pressure to drop to line resistance pressure.

Another type of open-center directional control valve is the manually engaged and pressure disengaged. This type valve is similar to the valve discussed in the preceding paragraph; however, when the actuating mechanism reaches the end of its cycle and the pressure continues to rise to a predetermined pressure, the valve automatically returns to the netural position and, consequently, to open-center flow.

One of the advantages of the open-center system is that the continuous pressurization of the system is eliminated. Since the pressure is gradually built up after the directional control valve is moved to an operating position, there is very little shock from pressure surges. This provides a smooth operation of the actuating mechanisms; however, the operation is slower than the closed-center system in which the pressure is available the moment the directional control valve is positioned. Since most applications require instantaneous operation, closed-center systems are the most widely used.

MOTION SYSTEM, DEVICE 21C5

Device 21C5, Submarine Advanced Submerged Control Trainer, simulates the diving and control stations of the SSN 637 Sturgeon Class submarines. Figure 5-4 shows a pictorial view of the device, and figure 5-5 is a simplified functional block diagram. The Honeywell DDP-124 digital computer exchanges data (through an interface system) with the trainee and instructor stations. The computer then performs all the mathematical and logic computations necessary to generate signals that drive the hydraulic and simulated submarine systems. (An in-depth study of digital simulator systems is given in chapter 8 of this manual.)

CAB MOTION, TWO DEGREES OF FREEDOM

The cab motion system functions to realistically impart the feeling of motion to the training operation by physically positioning the cab about the pitch and roll axes (two-degrees). The system is composed primarily of two electrohydraulic closed servo loops powered by a common hydraulic supply. The controlling inputs to these loops consist of attitude command signals supplied from the computing system. In the computing system, these signals are derived by inserting trainee-orders (involving steering and diving operations and changing ballast or trim) into the equations of submarine mass and motion. The cab motion system receives the resultant attitude command signals and orients the cab accordingly. This system is capable of positioning the cab to maximum limits of 45 degrees in pitch and 30 degrees in roll.

Cab motion about the pitch and roll axes is accomplished by mounting the cab within a gimbal ring assembly (fig. 5-4). The cab is supported at the fore and aft ends by self-aligning bearings mounted in pillow blocks. The pillow blocks are supported in trunnion mountings on the gimbal ring. The gimbal ring is similarly mounted at its pitch pivot points atop support pedestals which, in turn, are secured atop concrete platforms. The cab is thus free to move about the pitch and roll axes.

The cab and gimbal assembly is physically driven about both axes by hydraulically operated actuators controlled by the closed servo loops. The pitch actuator is mounted between the gimbal ring and the port pedestal. The roll actuator, which is mounted on the forward section of the gimbal ring, provides relative motion between the gimbal ring and the cab. In the event of a system failure, the liquid spring stops, located on the support pedestals, physically engage the gimbal ring at the end of its travel about the pitch axes.

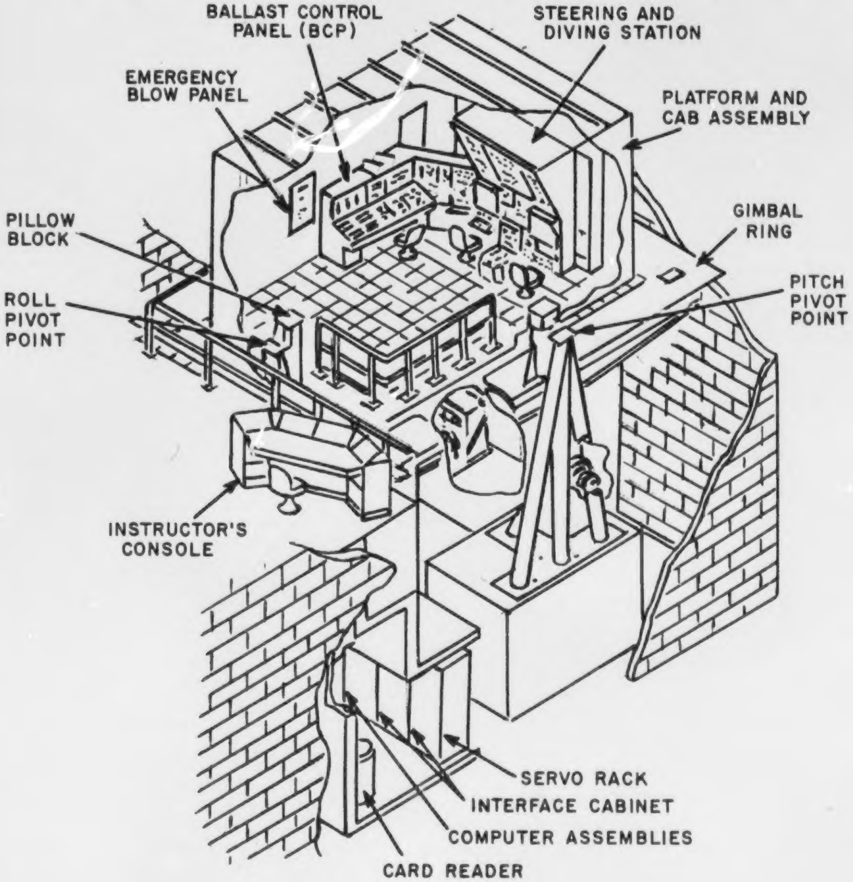

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Figure 5-4.–Submerged Control Trainer, Device 21C5.

Block Diagram Description

Since the operation of the pitch and roll sections of the system are similar, the block diagram shown in figure 5-6 illustrates components typical to both. With electrical power turned on, the cab gate closed and the platform unlocked, hydraulic power is available to the electrohydraulic servo valve. Initially, assume that the cab is at zero degrees in pitch and roll. Deflection of the operator's control (stick) positions the wiper of the command potentiometer. The output voltage of this unit represents control surface deflection and is applied to the computing system. Here, it is modified by other factors which affect submarine motion. The resultant signal is routed to the electrohydraulic servo valve.

The servo valve is a two-stage unit consisting of a pilot spool and a main valve. Signals from the computer cause current to flow in the torque motor. The motor moves the pilot spool, which in turn positions the main valve by means of a hydraulic pressure balance. Movement of the main valve meters hydraulic fluid to the actuator. The balanced-area actuator positions the cab, in pitch and roll, as commanded by the student operator. A feedback potentiometer, mounted on the actuator, senses piston

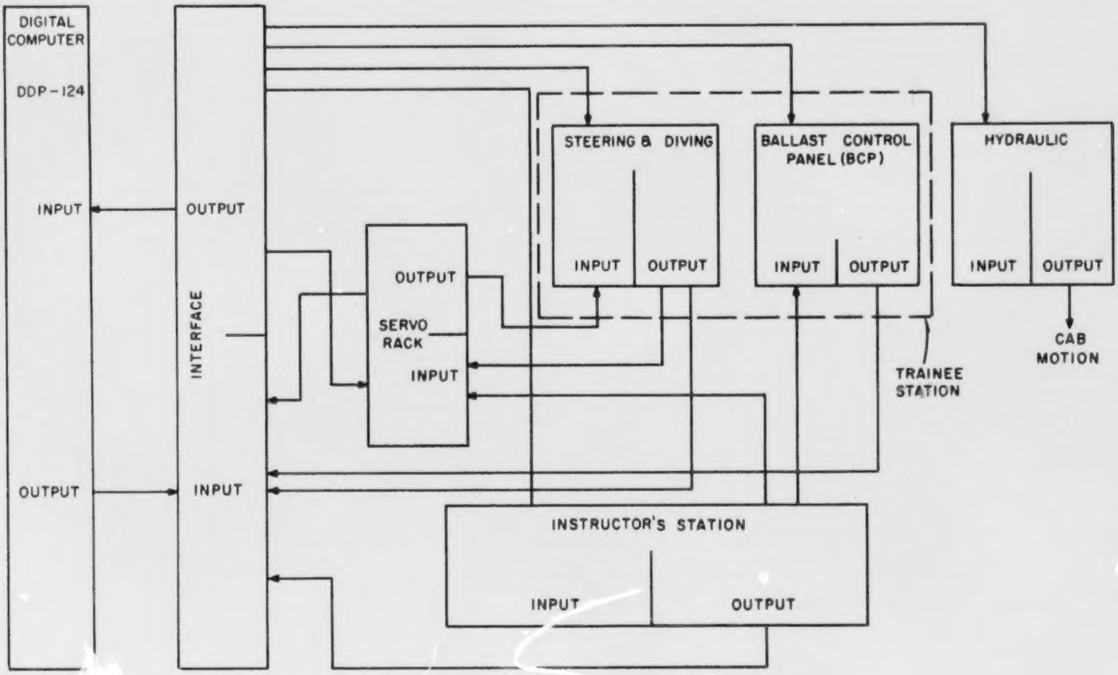

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Figure 5-5.—Device 21C5, Functional Block Diagram.

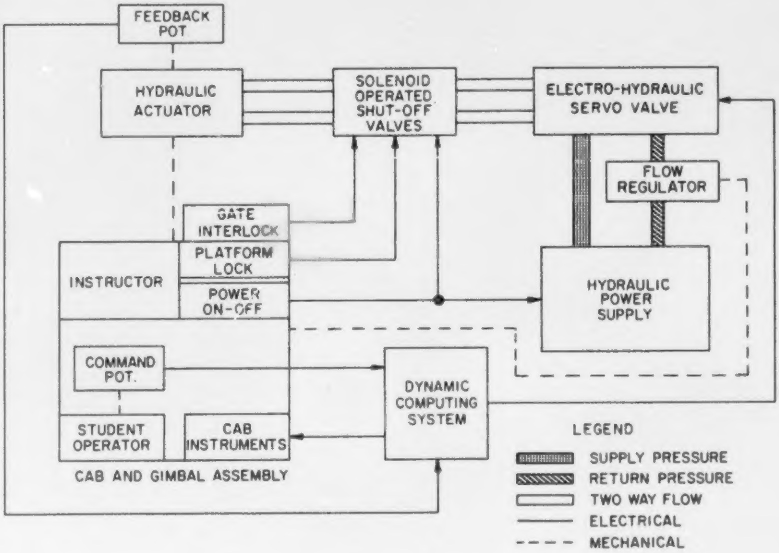

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Figure 5-6.—Cab Motion System, Block Diagram.

displacement and transmits a voltage proportional to cab rotation back to the computing system.

A flow regulating valve is installed in the return line of the servo valve. This valve limits maximum angular rates of cab motion. Solenoid actuated shutoff valves are located in the hydraulic lines between the servo valve and the actuator. During normal operation, with hydraulic power turned on, these valves are held open. The valves will shut off hydraulic flow to the actuator if the access gate is left open or the instructor actuates the platform lock switch.

The hydraulic portion of the cab motion system is shown in figure 5-7. Hydraulic fluid for system operation is contained in a 30-gallon reservoir. During a simulated tactical mission, the variable volume pump operates continuously. This unit draws fluid, through a filter, from the reservoir. A pressure compensator, contained in the pump, automatically regulates the volume delivered to the system by adjusting the length of stroke of the pumping pistons. Change of stroke length is controlled by system pressure. When the pump is operating at a pressure less than the maximum setting of the compensator, it delivers full volume. When the compensator pressure setting is attained, pump volume is reduced to the amount of flow required to maintain this pressure at the pump output. Pump discharge pressure is applied to a pilot-operated relief valve and, through filters and check valves, to pressure reducing valves and the pitch and roll servo valves.

The 3/4-inch pilot-operated relief valve protects the system by limiting hydraulic pressure to 3,000 psi. When pressure exceeds this preset value, the valve opens and discharges fluid from the supply line to the return line. A pressure gauge connected to the relief valve allows system pressure to be monitored. The check valves are spring loaded units which allow one way oil flow in the system. Flow in one direction overcomes a slight spring tension and opens the valve, while flow in the opposite direction firmly closes the valve thereby eliminating back pressure. The pressure reducing valves reduce line pressure to 800 psi. These units supply a constant pressure to the control points of the pilot stages of the pitch and roll servo valves. Line pressure is applied to the main stages of the valves.

The two-stage electrohydraulic servo valves are actuated by permanent magnet torque motors. Signals from the dynamic computing system, representing submarine motion, drive the torque motors. The torque motors impart very linear motion to the pilot spools. Direction and amount of spool travel is dependent on the polarity and magnitude of the applied signal. Movement of the pilot spool controls movement of the main spool through a pressure balance. The main spool meters and directs two way hydraulic fluid flow to the actuators.

Servo valve outputs are applied to the actuators through solenoid-operated shut off valves. When system power is applied, the solenoids energize and open the poppet valves, allowing oil to flow. Either opening the cab access gate, or engaging the platform lock switch deenergizes the solenoids. The actuators are balanced area, trunnion-mounted cylinders equipped with heavy duty piston rods. A cylinder with a 6-inch bore and a 22-inch stroke is used for the pitch actuator, and a 3-3/4-inch cylinder with a 16-inch stroke is used for the roll actuator.

Two back-to-back differential relief valves are installed across each actuator. These valves are set at 2500 psi and provide surge protection for the servo valves. Adjustable flow regulators are located in the servo valve return lines. These valves limit maximum angular rate of cab motion. The pitch flow regulator is set at 7.5 gpm, and the roll flow regulator is set at 3 gpm.

Return hydraulic fluid is routed through a filter to the pilot operated relief valve and the hydraulic oil cooler unit which is mounted on the motor-pump assembly. Flow through the oil cooler is controlled by a thermostat-actuated bypass valve. When the oil in the reservoir reaches the temperature set in at the thermostat, the valve closes and forces hydraulic flow through the oil cooler turbulators.

MOTION SYSTEM DEVICE 2F101

Device 2F101, T2C Operational Flight Trainer (fig. 5-8), is designed to train student

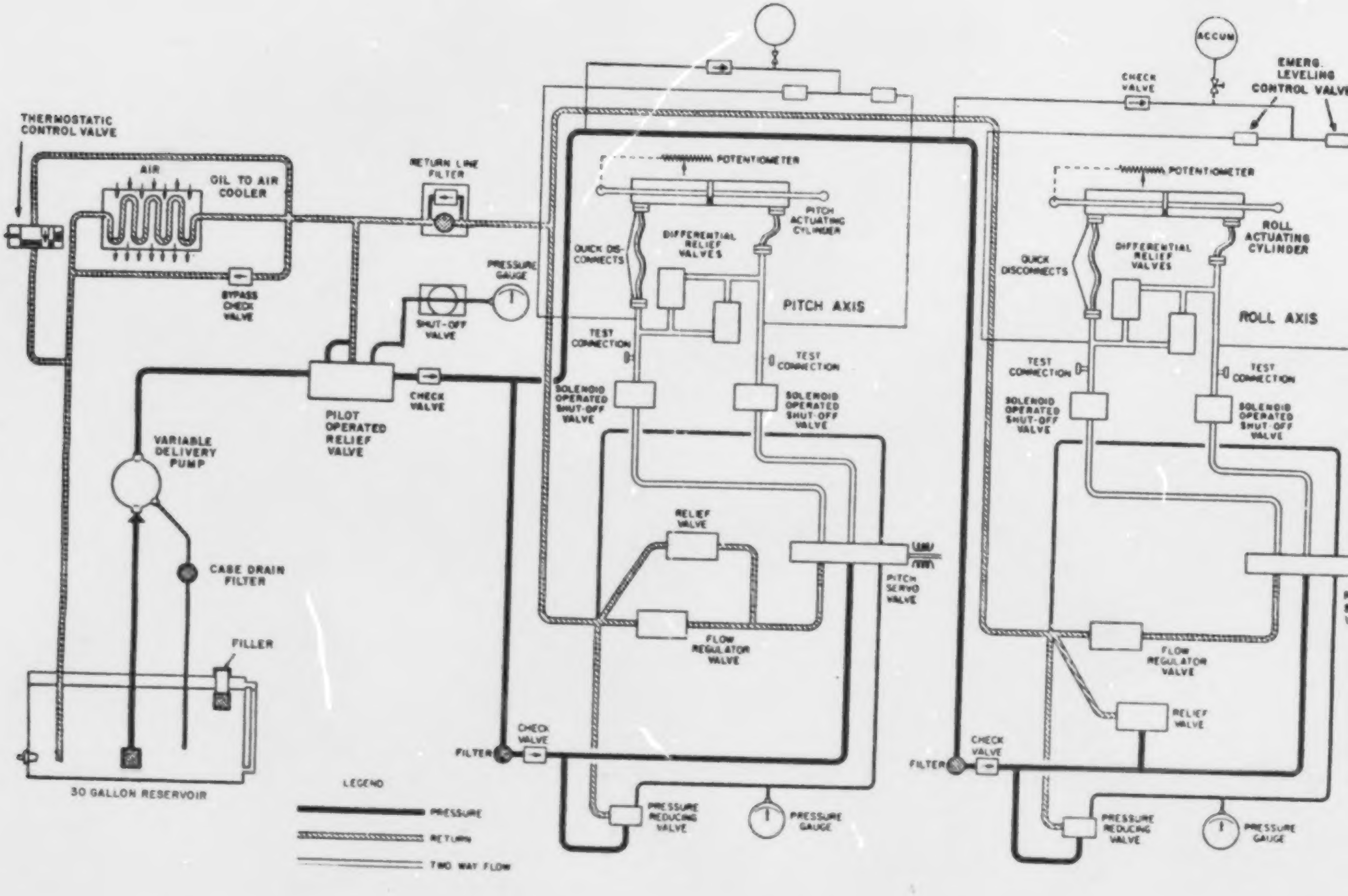

Figure 5-7.–Cab Motion System, Hydraulics.

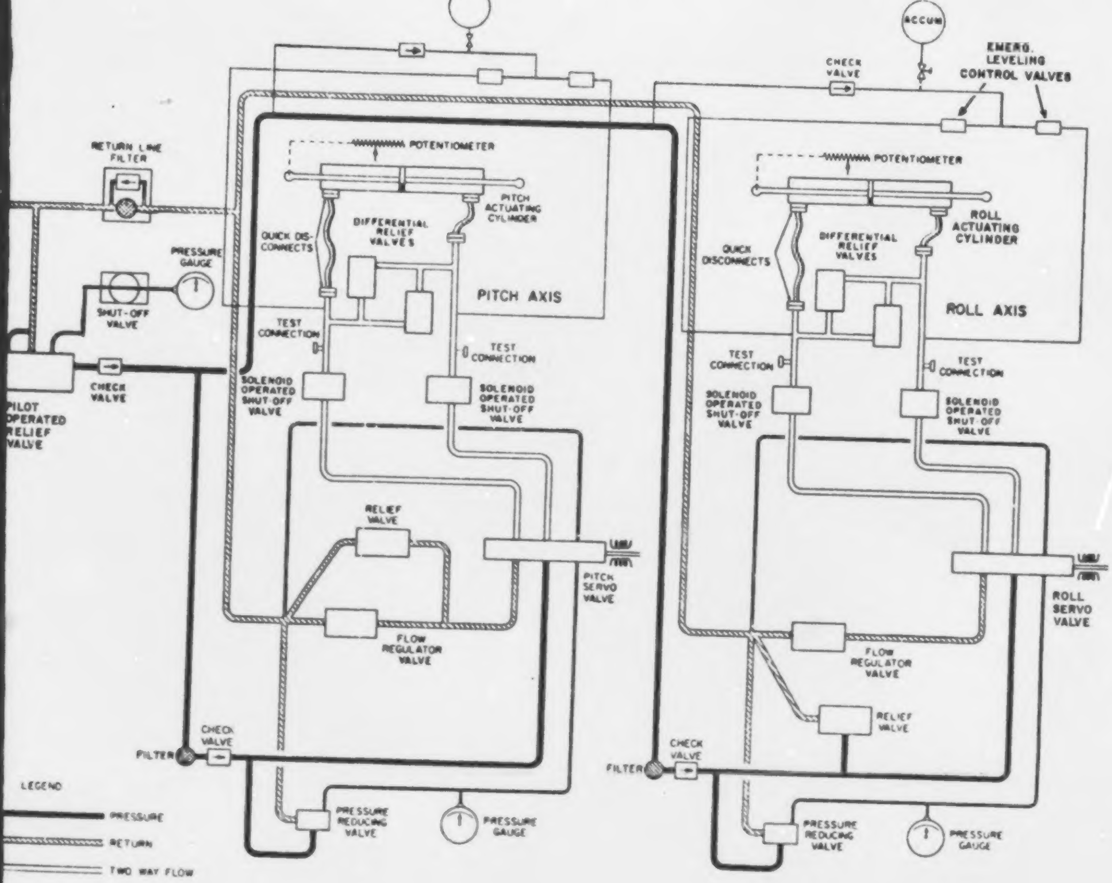

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Figure 5-7.—Cab Motion System, Hydraulics.

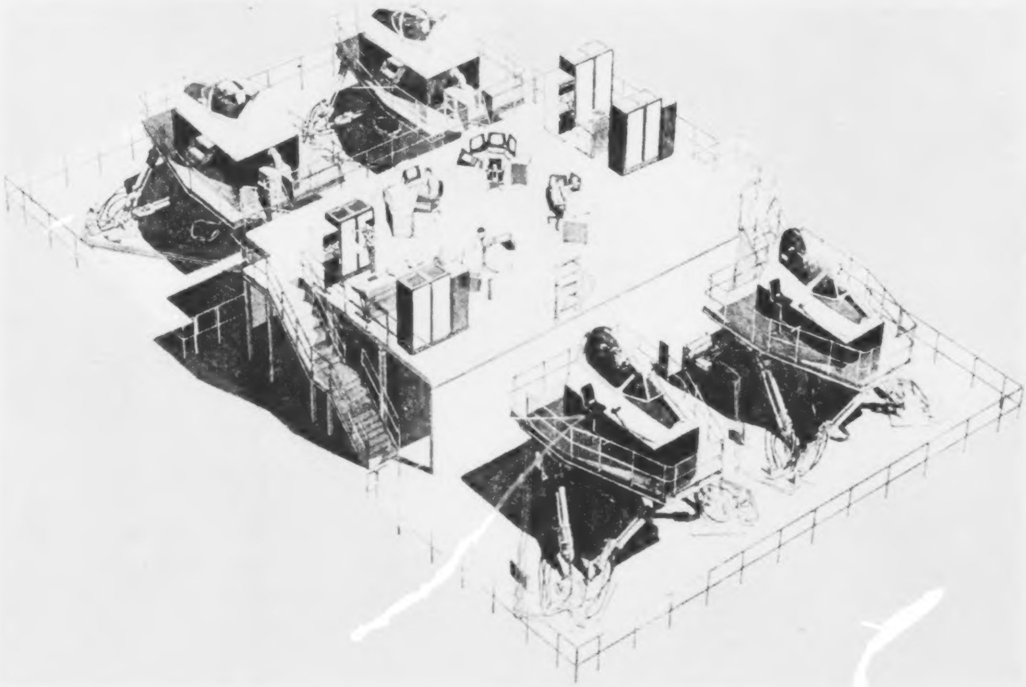

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Figure 5-8.—T-2C Operational Flight Trainer, Device 2F101.

pilots in aircraft control, shore-based and carrier-based procedures, and normal and emergency navigational and instrument flight procedures. The flight compartment of this device is mounted on a six-degree-of-freedom hydraulic motion system.

COCKPIT MOTION, SIX DEGREES OF FREEDOM

The cockpit motion system provides flight crews with realistic kinesthetic sensations of pitch, roll, yaw, vertical translation, lateral translation, and longitudinal translation. Since it is not possible to reach the velocities and physical excursions of the actual aircraft, motion cues are provided only in the most significant areas (onset of acceleration and deceleration), and are washed out before the excursion limits of the system are reached. This washout is gradual and does not affect the kinesthetic value of the motion cue.

The motion platform (fig. 5-9) is capable of independent motion in six degrees of freedom, achieved by the simultaneous and yet independent operation of the six hydraulic actuators (fig. 5-9, A-F). These actuators are arranged in three bipod pairs between the platform and the deck. Hydraulic fluid to each motion actuator is controlled by a four-way valve. The valves admit fluid to the motion actuators as a function of an input command signal. This input command signal is an analog drive voltage that is derived from the solution of dynamic equations by a digital computer. For normal operation of the platform, it is necessary for all six motion actuators to operate simultaneously.

Block Diagram Description

Figure 5-10 is a block diagram of the motion system showing the major components and their functional relationship. Hydraulic fluid is

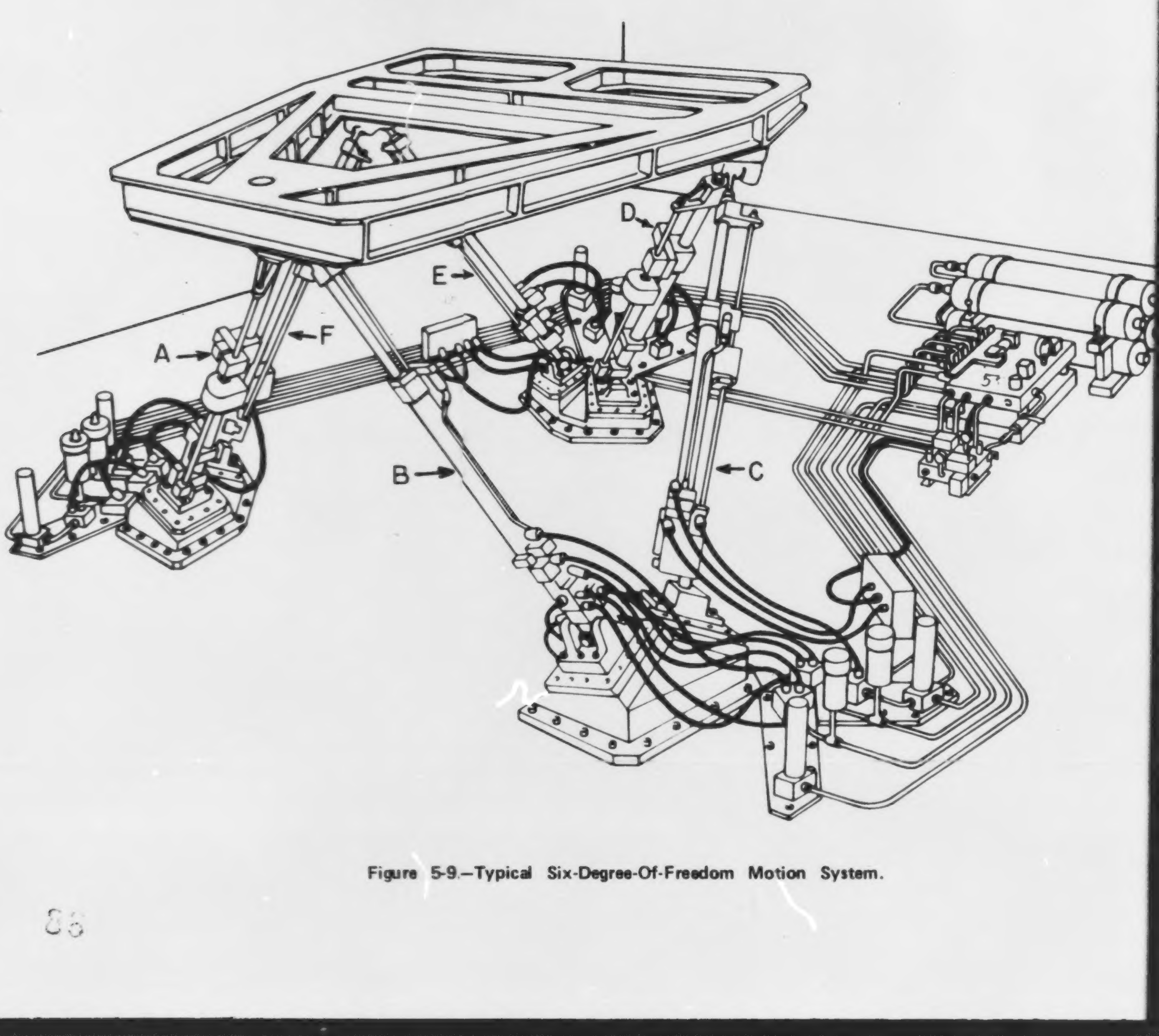

Figure 5-9.—Typical Six-Degree-Of-Freedom Motion System.

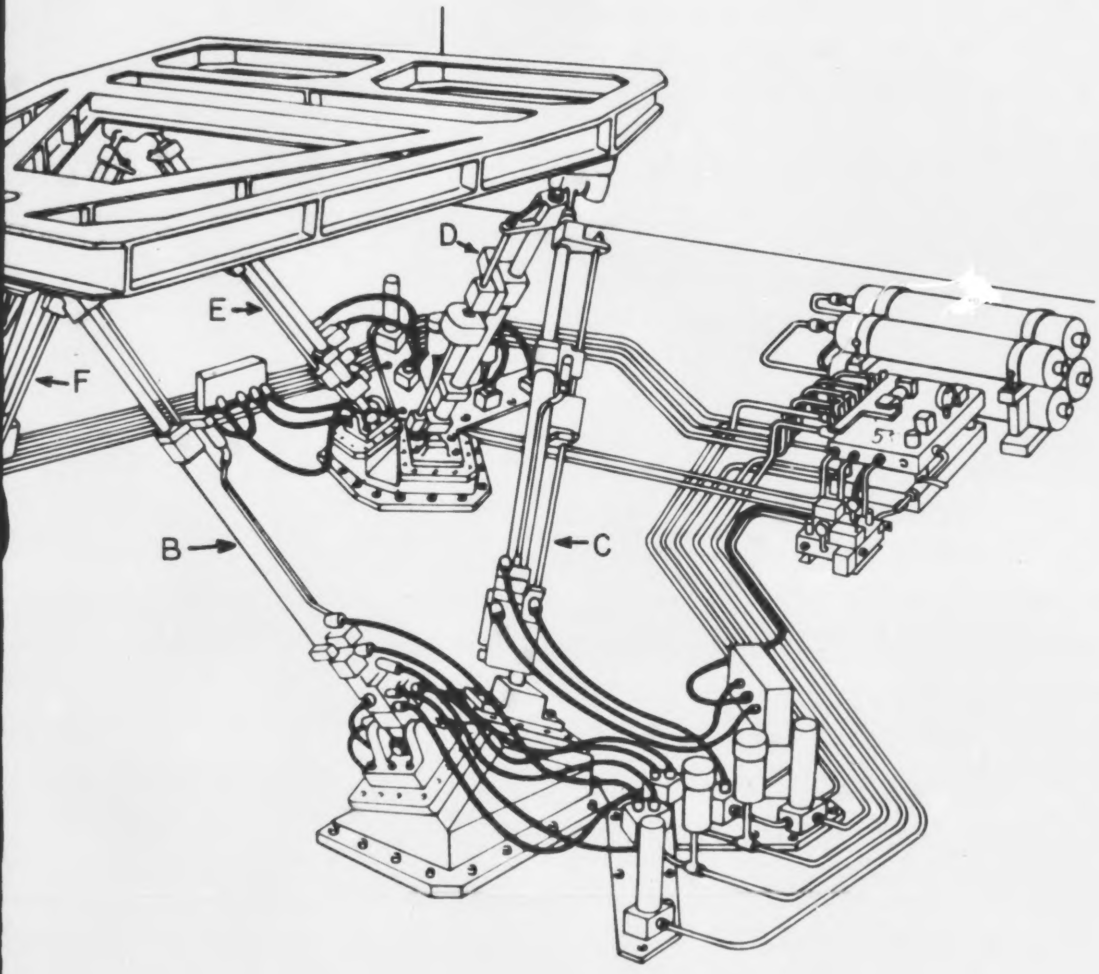

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Figure 5-9.—Typical Six-Degree-Of-Freedom Motion System.

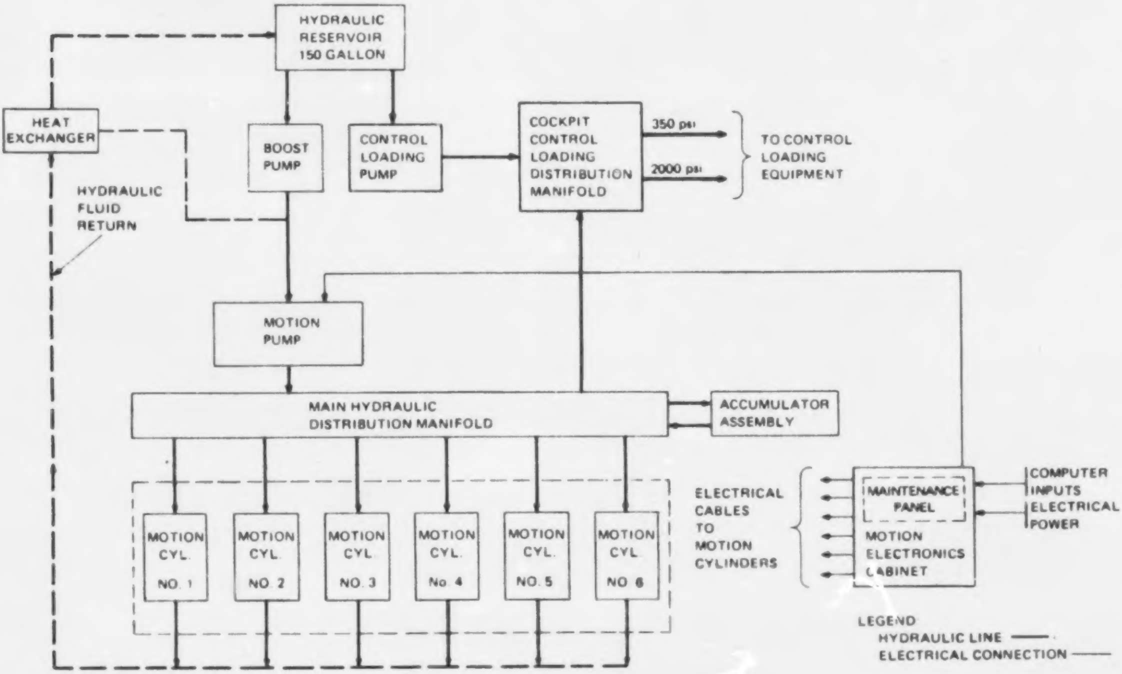

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Figure 5-10.–Motion System Block Diagram.

gravity-fed to the boost pump from the 150 gallon reservoir. The boost pump is used to furnish large quantities of hydraulic fluid to the motion pump unit. The pump unit furnishes up to 78 gpm to the motion system at a constant pressure of 2000 psi.

The output of the motion pump is applied to the main hydraulic distribution manifold. This manifold, located in the motion platform area, distributes fluid to the six motion cylinders. If conditions for a turn-on are satisfactory, the hydraulic power is slowly applied to the motion cylinders via a reduced flow solenoid valve located on the main hydraulic distribution manifold. If during normal operation, a condition such as low hydraulic pressure should arise, the automatic bleed valve on the motion pump will start reducing system pressure. When the hydraulic pressure is reduced to 500 psi, motion will shut down in an emergency manner. The motion cylinders will then return to the settled position at a safe rate of travel. An accumulator assembly connected to the main cylinder distribution manifold is used to assist system pressure and maintain it at 1200 psi when peak demands by the system tend to lower pressure. Fluid from the six motion cylinders is returned to the hydraulic reservoir through a heat exchanger to cool the fluid.

The motion electronics cabinet contains the necessary logic circuits, power supplies, servo amplifiers, etc., to control system operation and furnish analog drive signals to the motion cylinders. A maintenance panel in the motion electronics cabinet provides maintenance personnel with controls and indicators for monitoring and testing the motion system.

The cockpit control loading distribution manifold has provisions for two supply inputs.

Normally, a separate hydraulic supply pump (fig. 5-10) is provided as the primary source to the cockpit control loading distribution manifold, and a crossover line to the main hydraulic distribution manifold is provided as a backup supply.

System Operation

The hydraulic system develops and distributes, under electrical control, the hydraulic power for smooth and rapid response of the motion platform. The following paragraphs describe how this hydraulic power is developed to a working pressure of 2000 psi, and how, under electronic control, the fluid is admitted to the six motion cylinders as a result of command signals. The amount of fluid admitted to a cylinder determines the length of extension of that cylinder, and the relative length of the individual cylinders determines the attitude of the motion platform. Thus, with separate command signals for each cylinder, the platform can be made to assume any desired attitude within the mechanical limits of the cylinders.

Figure 5-11 is used throughout the following discussion. The numbers in parentheses in the following paragraphs correspond to the circled component identifier numbers in this figure.

HYDRAULIC PUMPS.–The hydraulic pumps are operated in the following manner.

Hydraulic fluid from the 150-gallon hydraulic reservoir (24) is gravity-fed to the boost pump (5) via a 100-micron strainer (4) and a manually operated ball valve (6A). The boost pump, driven by a three-horsepower motor (2), delivers up to 78 gpm of fluid at 30 psi to the intake of the motion pump unit. The boost pump will not run if the temperature switch (29) is actuated (fluid temperature above 150° F), if the fluid level switch (30) is actuated (fluid level below 100 gallons), or if the microswitch is actuated by the ball valve (6A) being in other than the fully open position.

With the 30 psi precharge pressure from the boost pump present at the inlet of the motion pump unit, the pressure switch permits the motion pump motor (13B) to start. Numerous interlock switches in the motion pump motor circuit prevent and/or interrupt motor operation if specific conditions are not maintained.

The motion pump (13A) is a pressure-compensated, variable-volume, axial-piston pump, capable of pumping from 0 to 78 gpm at a constant pressure of 1200 psi. Motion pump output is routed through a check valve (18) to the inlet of the bleed-down valve (21). The 10-gallon accumulator (19) is used to dampen line pulsations and maintain operation pressure (1200 psi) during peak demands by the system. The accumulator is precharged with nitrogen to 400 psi via the charging valve (20).

MOTION ACTUATORS.–The following paragraphs describe the hydraulic fluid flow to the six actuators that are the motion-inducing elements of the system. It should be noted that figure 5-11 shows only one of the motion actuators; the other five operate in an identical manner.

The 1.25-inch supply line from the motor pump is routed to the input of the main hydraulic distribution manifold (55). At this point, fluid is routed to the rod side of the six motion cylinders at full system pressure of 1200 psi. Note that the motion cylinder (71) is only a part of the motion actuator (59).

Fluid from the main motion turn-on valves is applied to the motion cylinder (71) via a 3-micron filter (77) and hoses (78) to the servo-controlled flow control valve (63). This valve controls fluid flow to the ram side of the cylinder as commanded by the drive signal program. From the flow control valve, the fluid passes through a deceleration valve (64) before entering the ram side of the cylinder. The ram side of the cylinder is determined by the direction in which the cylinder is moving. The deceleration valve is cam-operated to gradually reduce fluid flow to the cylinder and bring it to a smooth stop in the event the cylinder nears its mechanical limits (within five inches). The relief valve (66) is used to relieve fluid in the event pressure becomes excessive (above 2050 psi) in the cylinder. This excessive pressure could occur if, for example, the cylinder were in a down heave and all power were lost. The flow control valve (63) would close, shutting off the return path to the reservoir through valve (63), flow control valves (72), and hoses (81). This would

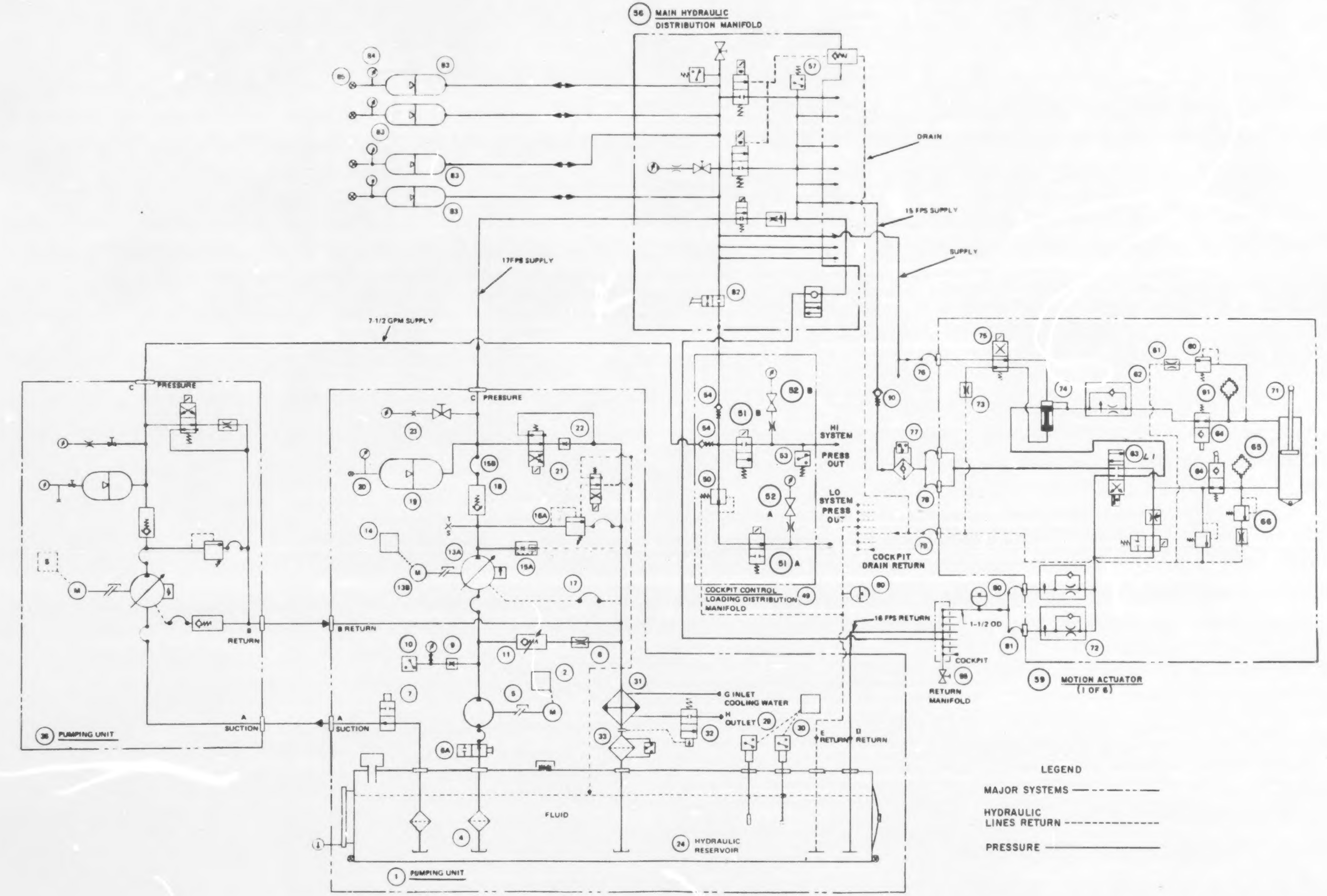

Figure 5-11.—Hydraulic System, Six Degrees of Freedom.

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cause the cylinder to act as a pump, producing a shock pressure that could damage components.

The driving force built up in the ram side of the cylinder is always working against the supply pressure of 1200 psi on the rod side of the cylinder. As mentioned previously, this pressure is applied to the cylinders from the inlet side of the main hydraulic distribution manifold, and is always present at the master cylinder, provided the motion pump is operating and system pressure is available. The fluid passes through a hose (76) to a four-way valve (75). If the motion system is on, this valve passes fluid to a shuttle valve (74), which in turn passes fluid to a flow control valve (62) through a deceleration valve (64) to the cylinder. The pressure transducers (65) and (91), sense the pressure on the ram side of the cylinder and furnish an electrical feedback signal to the servo amplifier which is compared with the command signal. If the difference between the command signal and feedback signal is excessive, relay contacts attenuate the signal to the servo-controlled flow control valve (63). If the motion system is off, a four-way valve (75) routes fluid to the shuttle valve (74), which closes and blocks fluid flow to the cylinder. The deceleration valve (64) and relief valve (74) operate in the same manner described for the ram side of the cylinder.

The return lines from the motion actuators are routed back to the hydraulic reservoir (24) through the return section of the main hydraulic distribution manifold. A one-gallon accumulator (80) is installed in the return lines to absorb pressure peaks.

The accumulator assembly, comprised of four 10-gallon accumulators (83), is connected directly to the supply lines at the main hydraulic distribution manifold. Each accumulator is precharged with dry nitrogen to a pressure of 400 psi. This assembly dampens line pulsations and maintains system pressure at 1200 psi during peak demands. Pressure gauges (84) are provided for monitoring nitrogen precharge on each of the accumulators. A two-way valve (11) on the main pumping unit (1) is normally open during motion-on. When the system shuts down, the valve closes, completing a return path to the hydraulic reservoir to slowly bleed system pressure through orifice (8).

The heated fluid is routed from the motion pump (13A) output to the heat exchanger (31) via a valve (21). The cooled fluid is returned to the hydraulic reservoir through a three-micron filter (33).

CONTROL LOADING.—The control loading manifold (49) distributes two separate supply pressures derived from a single hydraulic source. A high-pressure supply is provided for equipment requiring a hydraulic operating pressure of 1400 psi, and a low (reduced) pressure supply is provided for equipment requiring a hydraulic operating pressure in the range of 50 psi to 1600 psi.

The low (reduced) pressure supply is controlled and monitored by a pressure-reducing valve (50), adjustable from 50 psi to 1600 psi, and a hydraulic pressure gauge (52A), respectively. The normally closed solenoid valve (51A) controls the distribution of the reduced-pressure supply.

The high-pressure supply is equal to the hydraulic source pressure of 1200 psi. The normally closed solenoid valve (51B) controls the distribution of this hydraulic supply. Downstream of the distribution valve is a pressure gauge (52B) to monitor the output pressure, and an adjustable pressure switch (53). Normally, this pressure switch serves as a system interlock to ensure the associated systems are properly pressurized before computer drive signals are introduced.

The cockpit control loading distribution manifold has provisions for two supply inputs. Normally, a separate hydraulic supply pump (shown in figure 5-11 (36)) is provided as the primary source to the cockpit control loading distribution manifold, and a crossover line to the main hydraulic distribution manifold with a shutoff valve (82), is provided as a backup supply. Both input connections are equipped with check valves (54) to prevent any backflow of hydraulic fluid.

CHAPTER 6

CLOSED CIRCUIT TV: OPTICS, CAMERAS, CONTROL UNITS, TRANSMISSION

Whenever television is mentioned, most people immediately think of entertainment. The experienced Tradevman, however, will also associate television with its training capabilities. Actually, the growth of television and its applications has been so vast that TV is now used by schools, industrial plants, business establishments, stores, shops, and by all branches of government.

In this manual, we will consider TV as existing in two rather broad categories: COMMERCIAL TV AND CLOSED CIRCUIT TV. Commercial TV, for our purposes, is limited to the so-called entertainment TV as viewed on TV sets in people's homes. Closed circuit TV (CCTV), with which the TD is primarily concerned, is defined as TV which is transmitted mainly through wires or cables over relatively short distances, and intended for limited reception only.

Specific applications of CCTV include the following:

1. Observing distant points, such as blind-spots for aircraft traffic control around hangars and taxi areas.

2. Observing locations inaccessible to humans, such as monitoring water levels inside a boiler.

3. Controlling the handling of radioactive materials.

4. Instructing groups of trainees located at different places.

5. Enlarging an image as seen under a microscope or telescope to permit more viewers to observe the image simultaneously.

6. Viewing combat operations and communicating with combat crews by viewers at various locations.

7. Providing visual presentations for operational trainers.

In studying the CCTV system, it will become apparent that its operation closely resembles that of commercial telecasting. The major difference is in the method of transmitting the picture and sound from their origin to the monitor.

TRANSMISSION STANDARDS

As mentioned before, most CCTV transmission is accomplished by means of wires or cables. In some instances, however, CCTV transmission is accomplished by radiating a very low-power RF carrier at one of the commercial TV frequencies. This means of transmission is known as REMOTE OUTPUT. A standard commercial TV receiver, tuned to an otherwise unused channel, is used as the monitor.

The method of broadcasting an amplitude-modulated television signal is similar to the familiar method of broadcasting a standard AM radio signal. In both methods, the amplitude of an RF carrier is caused to vary.

In TV broadcasting, the high-frequency carrier is modulated by a composite video signal containing all the information needed for picture reproduction. At the receiver, the composite video signal is detected and used to reproduce the picture.

Since frequencies used for television broadcasting are considerably higher than those used for AM radio broadcasting, the TV signals are normally not reflected from the ionosphere. Thus, TV transmissions are limited to line-of-sight distances.

FREQUENCIES

Commercial television is broadcast on channels in the range of frequencies from 54 MHz to 890 MHz. This range includes both very high frequencies (VHF) and ultra high frequencies (UHF), and may be subdivided as follows:

1. Five low-band channels (2 through 6) in the VHF range occupy from 54 to 88 MHz.

2. Seven high-band channels (7 through 13) in the VHF range occupy from 174 to 216 MHz.

3. Seventy channels (14 through 83) in the UHF range occupy from 470 to 890 MHz.

Each channel is allotted a 6-MHz bandwidth for the transmission of the video and sound signals.

Table 6-1 lists all commercial TV channels and frequencies used in the U.S.

BANDWIDTH

A video bandwidth of 4 MHz is necessary in order to transmit pictures having good definition.

Commercial television is allocated a bandwidth of 6 MHz per channel, and each channel must contain both video and audio frequencies. Since a standard dual-sideband transmission of video alone would require an 8-MHz bandwidth, it is apparent that some adjustment must be made. To ensure operation stays within the alloted 6-MHz bandwidth, only a portion of the lower video sideband is broadcast. This is called the VESTIGIAL SIDEBAND method of transmission. Figure 6-1 shows the resultant RF spectrum in channels 2, 3, and 4 when this method is used.

SYSTEM COMPONENTS

A television system consists of the three basic units shown in figure 6-2: a camera, a control unit (or sync generator), and a monitor (or receiver). In more complex TV systems, accessory units such as optical multiplexers, special effects, video recorders, and audio units may be used in conjunction with the basic units.

The basic and accessory units and their electronic circuits will be discussed in this manual. A more basic review of most of these circuits is available in *Basic Electronics*, NAVEDTRA 10087 (Series).

CAMERA

The sequence of events which occur in a CCTV system starts in the camera unit, where a lens is used for focusing an image on the screen of a photosensitive tube. The type of lens is determined by the size of the scene to be televised, and may be a normal, wide-angle or telephoto lens. The sizes of the camera units vary from small palm-size mobile units to large fixed units mounted on special platforms.

CONTROL UNIT

The control unit (fig. 6-2), as the name implies, is the "heart" of the system. This unit connects all other units of the system together. In this unit, drive pulses are generated and used to develop the sweep, sync, and blanking signals required by the camera. The control unit mixes the sync and blanking signals with the raw video (from the camera) to form a composite video signal. The composite video signal is then sent to the receiver/monitor.

RECEIVER/MONITOR

The picture-producing unit (fig. 6-2) is commonly referred to as the receiver/monitor unit. The receiver and the monitor, as explained previously, differ basically only in the circuits contained in each unit. The media of transmission between the receiver and monitor units being different requires that the receiver employ additional circuits. (The media employed for the receiver is the atmosphere, while the

Table 6-1.—TV channel frequencies

Channel No.	Channel Freq. (MHz)	
2	54-60	lower VHF band
3	60-66	
4	66-72	
5	76-82	
6	82-88	
7	174-180	upper VHF band
8	180-186	
9	186-192	
10	192-198	
11	198-204	
12	204-210	
13	210-216	

UHF Band

Channel No.	Channel Freq. (MHz)	Channel No.	Channel Freq. (MHz)	Channel No.	Channel Freq. (MHz)
14	470-476	38	614-620	62	758-764
15	476-482	39	620-626	63	764-770
16	482-488	40	626-632	64	770-776
17	488-494	41	632-638	65	776-782
18	494-500	42	638-644	66	782-788
19	500-506	43	644-650	67	788-794
20	506-512	44	650-656	68	794-800
21	512-518	45	656-662	69	800-806
22	518-524	46	662-668	70	806-812
23	524-530	47	668-674	71	812-818
24	530-536	48	674-680	72	818-824
25	536-542	49	680-686	73	824-830
26	542-548	50	686-692	74	830-836
27	548-554	51	692-698	75	836-842
28	554-560	52	698-704	76	842-848
29	560-566	53	704-710	77	848-854
30	566-572	54	710-716	78	854-860
31	572-578	55	716-722	79	860-866
32	578-584	56	722-728	80	866-872
33	584-590	57	728-734	81	872-878
34	590-596	58	734-740	82	878-884
35	596-602	59	740-746	83	884-890
36	602-608	60	746-752		
37	608-614	61	752-758		

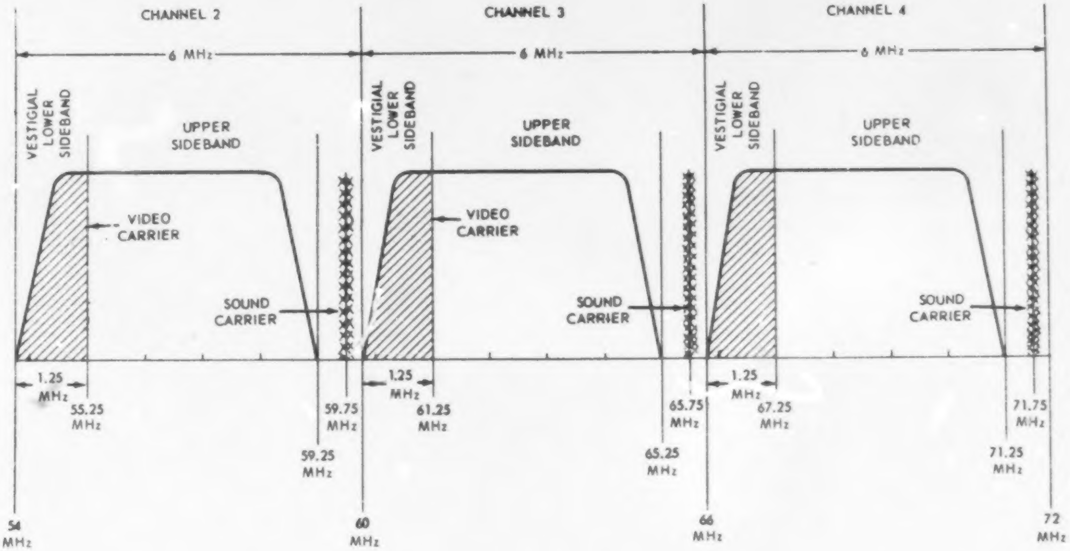

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Figure 6-1.—RF spectrum of TV channels 2, 3, and 4.

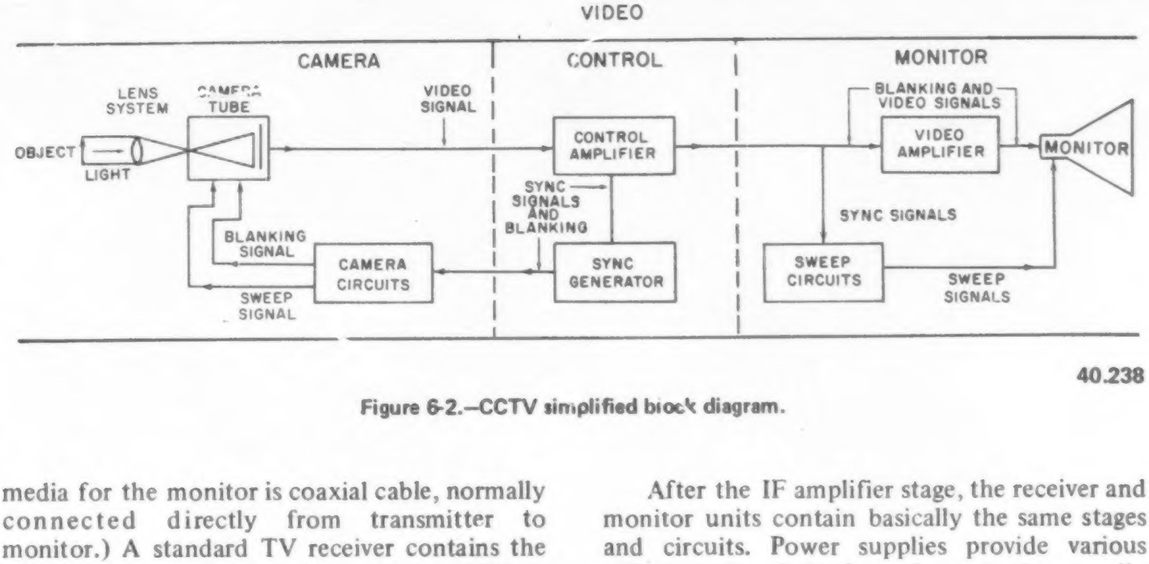

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Figure 6-2.—CCTV simplified block diagram.

media for the monitor is coaxial cable, normally connected directly from transmitter to monitor.) A standard TV receiver contains the same circuits as the monitor and, in addition, employs an antenna system, a tuner, and RF and IF amplifiers to receive the transmitted signals.

After the IF amplifier stage, the receiver and monitor units contain basically the same stages and circuits. Power supplies provide various voltages needed for the circuits; audio amplification is obtained from basically the same types of circuits used in standard radio receivers. Synchronization is accomplished through the use of a sync circuit; the horizontal and vertical sync signals are used to control the horizontal and vertical sweep circuits. Video amplification is accomplished in the various video circuits.

SCANNING

If a picture printed from a photoengraving (for example, a halftone picture in a newspaper) is examined with a magnifying glass, it is easy to see that the picture is composed of a large number of dots. The lightness or darkness of the picture or areas within the picture is determined by the amount of separation between the individual dots. The dots are the elements that make up the picture.

A television picture is formed in a similar manner. There is, however, one very important difference. In the picture made from a photoengraving, all elements of the picture are viewed simultaneously. In the television picture, the elements are presented individually, one after the other, but in such quick succession that the observer sees the picture as a whole. To transmit an image in this manner, it is necessary to employ a system of scanning; that is, the image is swept by an electron beam in a systematic manner, so that during a period of time all parts of the image are swept by the electron beam. Likewise, in the receiver where the image is reconstructed, a similar system of scanning is employed.

The principles of scanning can be illustrated by the following example. Assume you have a flashlight that can produce a very narrow beam of light, and you wish to view a picture on the wall of a dark room. Obviously, because of the narrow beam, you can view only a small portion of the picture at a time. If you can manipulate the beam very fast, the picture can be viewed in the same manner as the picture produced in television. To do this, start at the upper left corner of the picture and move the beam rapidly to the right along the top of the picture. When the right edge of the picture is reached, turn the beam off, and swing it rapidly to the left one beam-width lower. Turn the beam on again and sweep it rapidly to the right. Each sweep of the beam is a scan line. (In commercial television, there are 525 lines to a picture.) Continue this sequence until the light beam reaches the bottom right corner of the picture. One frame has been completed. Now turn the beam off and aim the flashlight at the upper left corner of the picture to start the scanning process over again.

In a camera tube, an electron beam of small diameter is formed and given the desired velocity by the electron gun located in the neck of the tube. Deflection (sweeping) of the electron beam across the mosaic plate in the camera tube is accomplished by deflection coils positioned around the neck of the tube.

A simplified illustration of scanning is shown in figure 6-3. The beam begins its scan at the upper left corner of the mosaic and moves horizontally along line 1 toward the right. The globules shown are exaggerated in size to simplify the illustration. All globules in line 1 are in the bright part of the mosaic. Therefore, they have lost the same number of electrons and have accumulated a uniform number of positive charges. As the beam sweeps across these globules, the charges are neutralized, and a relatively steady current flows from the metal coating of the mosaic plate, through a load resistor, through the B supply to the electron beam, and back to the associated globules. The same situation prevails while line 2 is being scanned.

Notice a part of the image is scanned in line 3, and current does not remain steady, but changes in value (through the load resistor) as the beam traverses this line. Current is steady (constant in value) until the fourth globule is reached. From 4 through 13, the globules have a slight negative charge and cause current through the load resistor to decrease (when the beam sweeps across the black globules). Beginning with globule 14, the output current is increased again. In line 4, current through the load resistor remains steady until the beam reaches globule 4, then current decreases. When the beam is on globule 5, current through the load resistor increases and remains steady until the beam reaches globule 13. Current decreases when the beam is on glouble 13 and increases when the beam strikes globule 14. Current through the

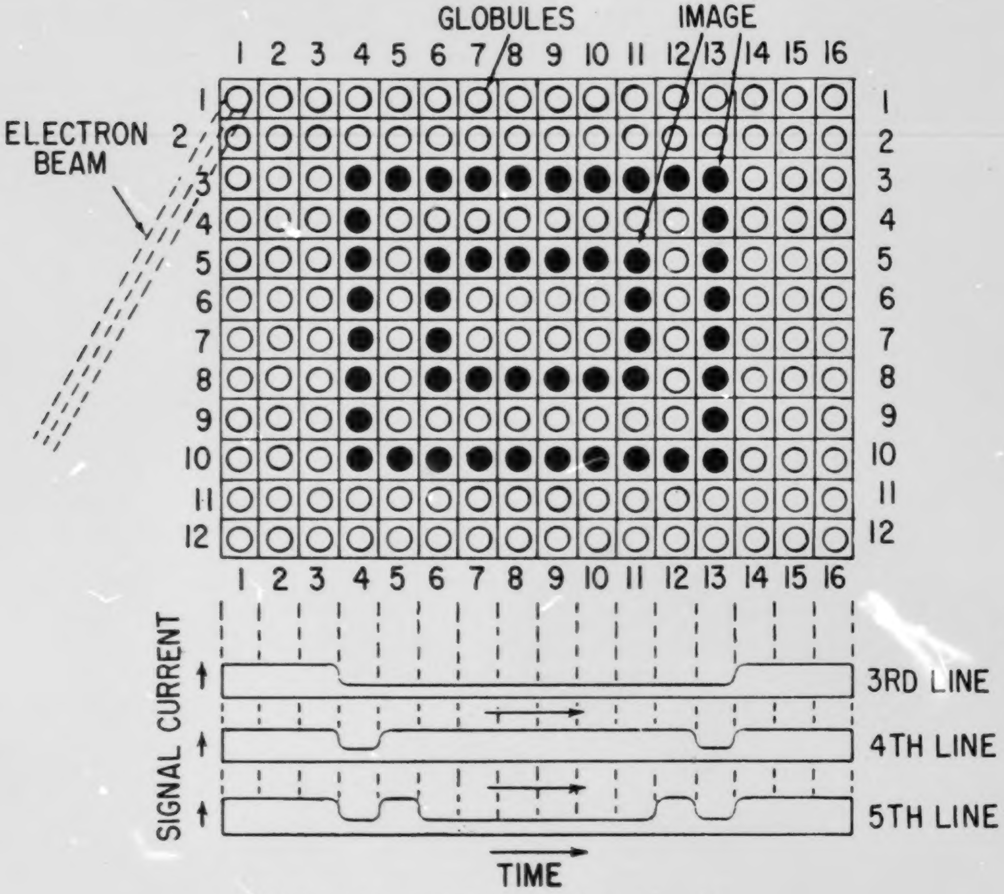

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Figure 6-3.–Simplified illustration of scanning.

load resistor then remains steady through the rest of line 4.

When line 5 is scanned, current through the load resistor is steady as the beam scans globules 1, 2, and 3. Current decreases for globule 4; comes back to the steady value for globule 5; decreases for globules 6 through 11; goes to the steady value for globule 12, decreases for globule 13; and returns to the steady value for the rest of the line. The relative strengths of the signal currents are shown at the bottom of figure 6-3.

In a practical camera tube, the globules are extremely small and close together, so the picture can have great detail. Therefore, many changes in current will occur during the course of a single scan. Tiny pulses of current through the load resistor develop signal voltages that are applied to the input of the video amplifier. In order that all of these signal voltages pass through the amplifier, it must be capable of passing a wide band of frequencies.

BANDPASS REQUIREMENTS

When speaking of bandpass requirements of an RF or a video amplifier, we are referring to the range of frequencies which must pass through the amplifier. For code work, where only one frequency is concerned, a very narrow bandpass (as low as 100 Hz) can be used. Bandpass requirements for television are much greater and some idea of these requirements may be gained from the following explanation.

Assume each line to be scanned contains 1,000 globules, each insulated from the other. Assume also the diameter of the electron beam is approximately that of a globule, and each adjacent globule has a different charge.

In a standard commercial television system used in the United States, 525 lines are scanned by the electron beam in tracing over the entire mosaic plate in the camera tube. As will be shown later, some of these lines are lost during the beam retrace (blanking) time. The surface of the mosaic is completely scanned 30 times in 1 second. Therefore, the number of lines scanned in 1 second is 525 x 30 = 15,750; this is called the horizontal sweep frequency.

The number of globules (each having a charge proportional to the intensity of a particular element) contained in 1 line is assumed to be 1,000. Therefore, the number of picture elements in the image each second is 15,750 x 1,000 = 15,750,000.

If the period of a complete cycle is assumed to be the period of the change in signal voltage developed as the beam passes across 2 successive globules, then the frequency is 15,750,000 ÷ 2 = 7,875,000 Hz. In order to reproduce all of the picture elements perfectly, the transmitter (and receiver) circuits must be able to pass, without distortion, a band of frequencies approximately 7.87 MHz wide. The quality of the picture detail is called resolution.

In actual practice, it is not necessary to pass a band of frequencies this wide. There are less than 1,000 picture elements per line, and each globule of light-sensitive compound may not be charged differently from its neighbor. Because of these and other considerations, a bandpass of 4 MHz can be used to obtain satisfactory results.

Assume that a bandpass of 4 MHz is used. How much horizontal detail (bits of picture detail on a horizontal line) is then possible? The period of a 4 MHz signal is 0.25 μs, the time required by the electron beam to scan across 2 adjacent elements. Because 15,750 lines are scanned in 1 second, the period of 1 line is 63.5 μs. From this, the time used during retrace (10.2μs) is subtracted to give the actual period of 1 line. The period of 1 line is 53.3 μs, and the number of cycles per line is 53.3 ÷ 0.25 = 213 (approx.), and the number of elements per line is approximately 2 x 213 = 426.

Vertical detail depends on the number of horizontal lines scanned per picture frame. This may be illustrated by referring to figure 6-3. Assume that in line 3 each black dot (picture element) is divided into 2 dots and placed one above the other within the confines of line 3. When the beam scans the line, both dots are covered simultaneously and only one signal is available as the output. If the beam width is decreased, and twice as many lines are scanned, a signal is produced from both black dots; that is, the vertical detail is improved.

In a complete scan of one picture frame, many lines are lost during beam flyback time. These lines are not effective in producing vertical detail. It may be assumed that 380 horizontal lines are effective in producing vertical detail. The number of picture elements per frame is 426 x 380 = 161,880; and at 30 frames per second, the total number of cycles produced is 161,880 x 30 = 4,856,400.

As previously stated, a bandpass of 4 MHz gives satisfactory results.

FLICKER

The eye can retain an image for a fraction of a second (about 1/15 second) after the image is formed on the retina. This characteristic of the eye is utilized when we look at moving pictures and at television.

A moving-picture film is composed of a series of individual pictures (frames) that are shown on a screen in quick succession. The illusion of motion comes about because the figures in a given frame may be displaced slightly in succeeding frames; and if enough frames are shown per second, the figures appear to move (because of the rapid sequence of the frames and the persistence of vision). At approximately 15 frames per second, the motion appears continuous, but there is a pronounced flicker. At 24 frames per second, some flicker is present; however, it is much less objectionable than the flicker at 15 frames per second. To further reduce the flicker, a special shutter arrangement is used. The shutter cuts off light from the screen while a new frame is being moved into position. It also cuts off light from the screen again while the picture frame is stationary. Thus the shutter divides the presentation of each frame into two equal time intervals. This has essentially the same effect on flicker as increasing the frame frequency from 24 frames per second to 48 frames per second.

INTERLACE

In television, similar problems are encountered. To keep flicker from becoming objectionable, 30 complete frames per second are shown. Flicker is further reduced by the use of interlaced scanning, which has essentially the same effect as increasing the frame frequency from 30 to 60 frames per second. The horizontal scanning speed and bandpass requirements of the composite TV signal remain the same.

Interlaced scanning is illustrated in figure 6-4. As mentioned before, bandpass considerations, synchronization problems, and the necessity for detail led to the selection of 525 horizontal scanning lines per frame. To reduce flicker by means of interlaced scanning, the electron beam is made to scan the odd-numbered lines first and then the even-numbered lines. Thus, two scans (fields) are necessary to complete one frame. For example, as shown in figure 6-4, the sweep for the first field begins on the left side of line 1. The beam moves across the image plate at a slight downward angle (moved downward by the magnetic fields of the vertical deflection coils). At the end of the line, the electron beam is blanked out during its retrace to the left side of line 3. This process is continued until the middle of line 525 is reached (only 25 lines are shown in the figure). Therefore, 262.5 lines are scanned in the first field. When the beam reaches the middle of the last line, it is blanked out and returned to the middle of line 2 where the sweep for the second field starts. The even-numbered lines are then scanned in sequence until the end of line 524 is reached. At that instant, the beam is blanked out and returned to the beginning of line 1, and the whole process is repeated.

In order to keep the movement of the electron beams in both the camera and picture tubes in step, and in order to blank out the signals from the picture tube during the horizontal and vertical retrace periods, synchronizing and blanking signals are transmitted by the transmitter.

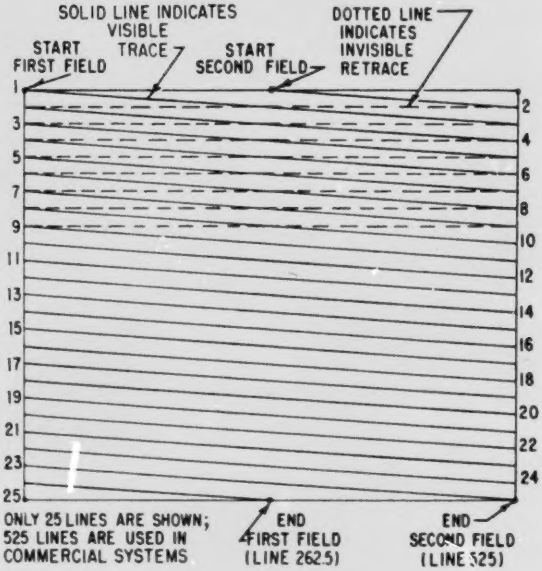
SOLID LINE INDICATES VISIBLE TRACE
START FIRST FIELD
START SECOND FIELD
DOTTED LINE INDICATES INVISIBLE RETRACE
1
3
5
7
9
11
13
15
17
19
21
23
25
2
4
6
8
10
12
14
16
18
20
22
24
ONLY 25 LINES ARE SHOWN; 525 LINES ARE USED IN COMMERCIAL SYSTEMS
END FIRST FIELD (LINE 262.5)
END SECOND FIELD (LINE 525)

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Figure 6-4.–Interlaced scanning.

COMPOSITE SIGNAL

Blanking signals (voltages) are used in both the camera tube and picture tube control circuits to cut off the electron beam at the end of each horizontal scan line and each horizontal sweep so that the return trace is not active in producing picture signals at the transmitter and picture elements at the receiver. Blanking signals are also used to blank out the vertical return trace following the scan of each field.

Included with the blanking voltages (actually superimposed on them), are the synchronizing pulses that trigger the vertical sweep circuits and synchronize the horizontal sweep circuits of the receiver/monitor. The horizontal sync pulses trigger the horizontal sweep (at the correct instant) 15,750 times a second. The vertical sync pulses trigger the vertical sweep (at the correct instant) 60 times a second.

For horizontal scan, the sequence is as follows:

1. The beam (sweep) is blanked out when the sweep reaches the right side of the screen.
2. An instant later, the horizontal sync pulse arrives and the sweep retraces to the left side of the screen.
3. The next horizontal sweep begins.
4. An instant later, the blanking pulse is removed and the sweep is visible until it reaches the right side of the screen.

For the vertical scan, the sequence is as follows:

1. The beam (sweep) is blanked out at the end of the first field (at the end of line 262.5).
2. The vertical sync pulse arrives and the sweep retraces to the middle of line 2 at the top of the screen.
3. The next vertical sweep begins.
4. The blanking signal is removed.

During the second field, the lines missed on the first field are filled in.

In order to keep the horizontal sweep locked in step during the vertical retrace period, and in order to produce interlaced scanning, the vertical sync pulses are serrated and both preceded and followed by equalizing pulses. The composite video signal (the complete signal, including video and sync pulses), particularly the vertical and horizontal sync pulses, will have more meaning when the method of separating these pulses is described later in the chapter.

All television receivers must be able to select the desired carrier frequency, amplify the required band of frequencies, separate and demodulate the video and audio frequencies, separate and utilize the sync pulses, and reproduce the picture on the screen and the sound at the loudspeaker. How well each of these functions is accomplished depends, in a large measure, on the design and quality of the TV receiver.

When the signal in closed circuit TV is transmitted from the camera unit to the viewing unit via cable, there are no antenna problems. However, where the control unit utilizes a transmitter, which radiates a low-power amplitude-modulated RF carrier, the viewing unit must have a tunable receiver.

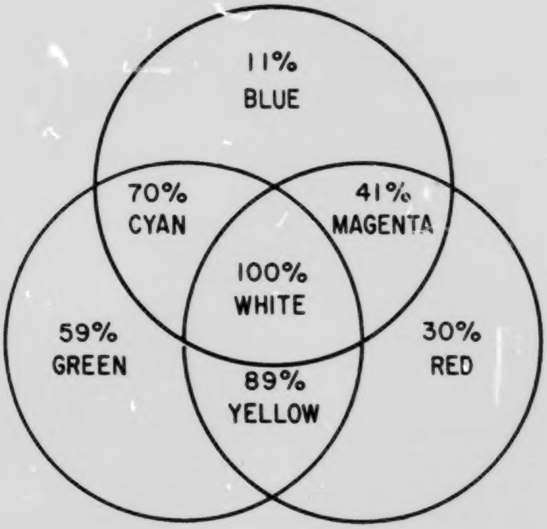
OPTICS

One of the most important parts of a television system is the optical system. This system must capture all the detail of the viewed scene so the camera tube can produce a good picture for transmission.

The principles of light contained in *Tradevman 3 & 2*, NAVEDTRA 10376 (Series), should be reviewed before you read further in this manual.

COLOR OPTICS

The principles of color presented in the following paragraphs apply specifically to the development of color television pictures. The three primary colors, red, green, and blue, (fig. 6-5), are used in television. A primary color,



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101 **Figure 6-5.—The additive primaries.**

when combined with another primary color, produces a different color.

Referring to figure 6-5, it can be seen that the three large circles represent the three primary colors. In the center where all three overlap, the color white is formed. In sections where two primaries overlap, another color is produced: green and blue produce cyan (greenish blue); blue and red produce magneta (bluish red); red and green produce yellow.

The combining of two primary colors, in proportional amounts, produces the new color. However, when all three colors are combined as units and in percentage of color, the result is white. Note the following combination:

1. One red unit represents 30 percent red.

2. One green unit represents 59 percent green.

3. One blue unit represents 11 percent blue.

When one unit of green light is combined with three units of red light, the result is orange. By changing the proportions of red and green, a variety of colors between red and green can be produced. As the proportion of a primary color mixture changes, the resultant color also changes.

A color by itself is called a hue. Green leaves have a green hue; a red apple has a red hue. Different hues result from different wavelengths of light. Red has the longest wavelength; violet the shortest.

The term saturation indicates the amount a color is diluted by white light. The more a color differs from white, the greater is its saturation. A weak blue color has little saturation, but vivid blue is highly saturated. Saturation is further described by the terms purity and chroma.

The brightness of a color as perceived by the human eye is called luminance. The human eye sees brightness increase from blue to a peak at green and then decrease again to red. This apparent response curve is used as the standard CIE (International Commission of Illumination) luminosity (brightness) curve.

Color resolution is the full three-color reproduction of the red, green, and blue primaries. Monochrome (black and white) reproduction is used in TV for the smallest details. For example, in a televised picture of an automobile, the entire body of the car would be in full color, the narrow vertical strips on the frame would probably be reproduced in two colors, and the outline of the car where it joins the background would be in black and white.

LENS CHARACTERISTICS

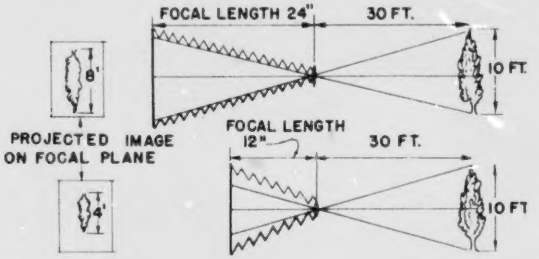
Since lenses were used in photography long before they were used in television, it is natural that much of the terminology relating to lenses is expressed in photographic terms. Be assured, however, that references to photographic characteristics in the following discussion also apply to TV optical systems.

The optical term lens is applied to a piece of glass which is bound by two spherical surfaces. The term lens is also commonly used to refer to a photographic objective. The term photographic objective indicates that several simple lenses have been combined as elements in an optical instrument used to form a real image of an object.

Lenses are the basis of many principles peculiar to photography. If a TD wishes to make the best use of lenses, he should become thoroughly acquainted with these principles and related terms. A discussion on the most important terms follows.

Focal Length

The image formed on a screen by a lens is sharp at the point where the marginal rays and the rays passing through the lens along its optical axis meet. If these incident rays are parallel when they reach the lens, they converge or come into focus at a distance of one focal length behind the lens. The focal length of a lens is equal to the distance from its optical center to the camera focal plane when it is focused on an object at infinity. The focal length of a lens is an inherent factor that cannot be changed. This factor is determined by the formation (diameter and thickness) and curvature of the lens. Focal length is frequently employed to indicate the size of a lens. Thus, a lens labeled as an 8-inch lens (F.L. 8 in.) indicates that when it is focused on a point at infinity, the distance from its



40.157

Figure 6-6.—Effect of focal length on image size.

optical center to the focal plane is 8 inches. This distance (8 inches) is the nearest distance at which such a lens will sharply focus an image. The thickness and diameter of the lens affect focal length. The index of refraction for the lens material also affects focal length.

The focal length of a compound lens is often referred to as equivalent focal length. This means the focal length of a modern compound lens is being compared to the focal length of a simple thin lens which would give an image the same size.

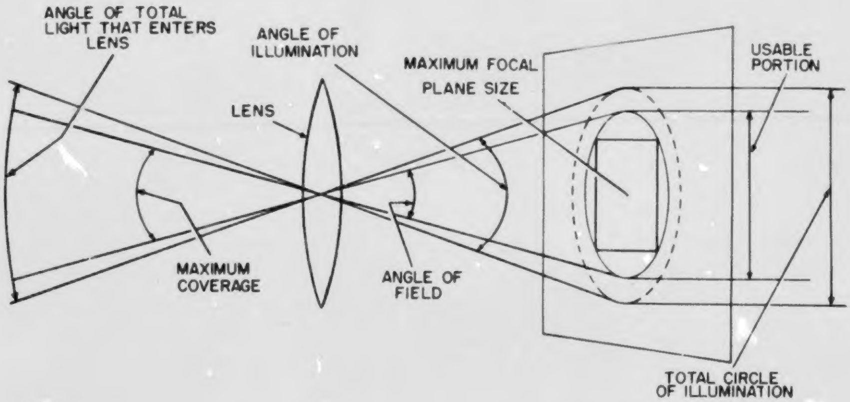
When a lens is used in a TV camera, it must be placed at a certain distance from the focal plane to obtain a sharp image. As shown previously, this distance is actually controlled by the focal length of the lens and the lens-to-object distance. Therefore, with a given object size and a given object distance, the lens focal length determines the size of the image. This means the longer the focal length of the lens, the larger the image; the shorter the focal length of the lens, the smaller the image. The effect of focal length upon image size is illustrated in figure 6-6.

The figure shows that when two cameras having two different focal lengths are placed at an equal distance from an object, the images formed have different dimensions. At any given distance, the lens focal length controls image size. The lens with a focal length of 12 inches forms a smaller image than the lens with a focal length of 24 inches. The image formed by the 24-inch lens is twice as large as the image formed by the 12-inch lens.

The Field of a Lens

The beam of light passing through a lens is cone shaped (due to refraction). The large end of the cone spreads over a circular area at the focal plane. The usable portion of this lighted circle is the field of the lens. (See fig. 6-7.)

Two lines drawn from the center of the lens to opposite ends of any diameter of this field form the angle of field of that lens. Likewise, lines may be drawn from the lens to opposite



40.158

Figure 6-7.—The field of a lens.

ends of the focal plane, and the angle formed by the lines is the angle of view. The field of a lens, the angle of field, and the angle of view are illustrated in figures 6-7 and 6-8.

By studying figure 6-8, it should be apparent that angle of view is a flexible term, governed by the size of focal plane used and its position in the field of the lens. If the focal plane is moved too far aside from the axis of the lens, part of it might lie outside the angle of field. In this case, the portion of the focal plane outside the field would not receive an image. The remaining section of the focal plane could cover a very narrow angle of view.

No lens produces a usable image over its entire field. The image formed around the edges of the field is always blurred. This blurring occurs to a greater extent with some lenses than with others. Nevertheless, the angle of view of a lens is always a smaller area within the field of a lens and is never as large as the field of the lens.

TYPES OF LENSES

The type of image or the size of camera coverage desired requires different types of lenses. The sizes of the lenses (fig. 6-9) vary from small and short to large and long. the purposes of the various lenses vary from the wide-angle lens for large-area coverage to the telephoto lens for narrow coverage at long distances.

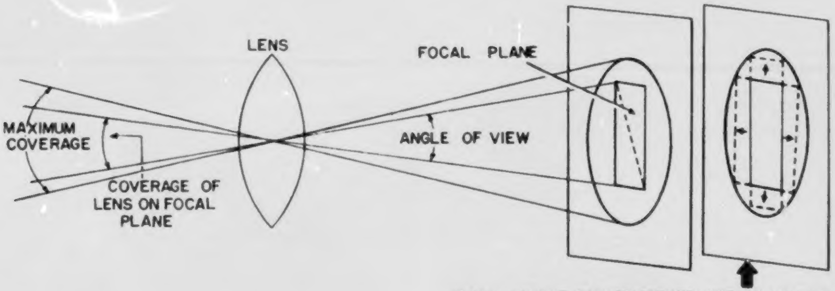
A special lens called the "zoom" lens is used for special effects. This lens can be varied from normal visual coverage to distant closeups. In some TV cameras, the lens is manually adjusted; in other TV cameras it is motor driven. The lens may be adjusted manually or by an automatic motor-driven device.

FOCUSING

Adjusting or changing the distance between the focal plane and the camera lens is termed focusing. To aid in accurate focusing, cameras of the view-and-press type have a focusing screen, a piece of ground glass placed at the focal plane of the camera on which the subject is focused. This device provides a definite plane on which the eyes may focus, and ensures the images formed by the lens is focused on the same plane. The focusing screen should never be confused with the focal plane.

When the distance from the lens to the object focused on is changed, there must be a corresponding change in the distance from the lens to the focal plane.

When the lens is focused on an object so distant that the light rays reflected from it are essentially parallel, these rays converge, after refraction by the lens, at the point of principal focus. The point of principal focus is on the principal focal plane which is at a distance of



FOCAL PLANE CAN BE MOVED WITHIN USABLE PORTION OF THE CIRCLE OF ILLUMINATION AS SHOWN BY THE DOTTED LINE

40.159

Figure 6-8.—Angle of view.

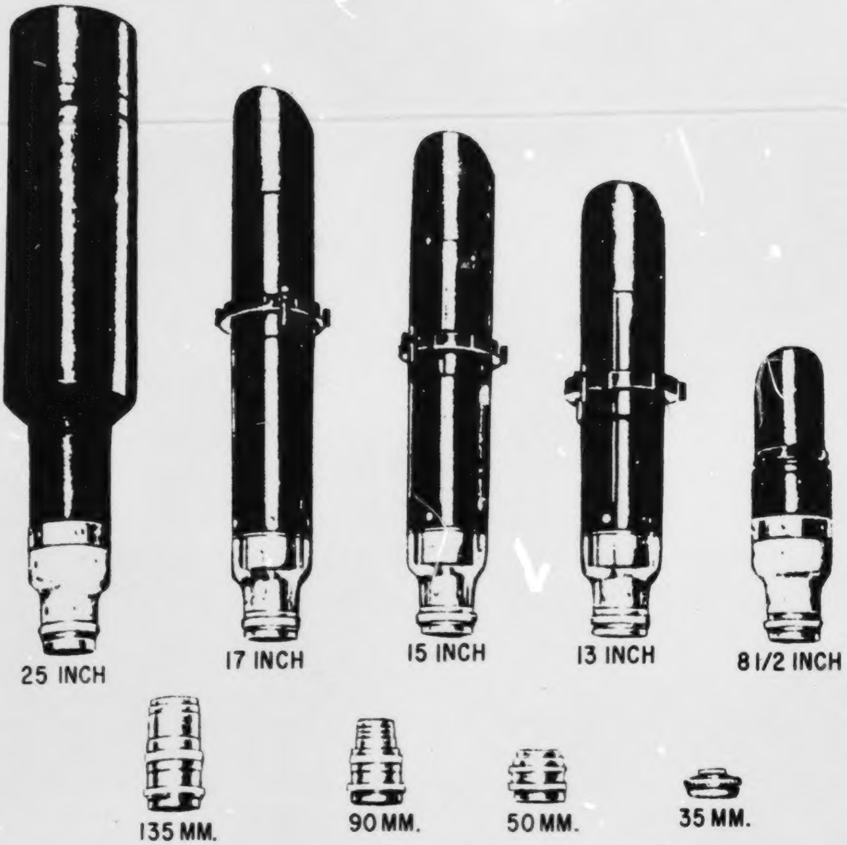


Figure 6-9.—TV camera lenses. 40.160

one focal length behind the lens. Therefore, the lens is said to be on infinity focus.

If this distant object is moved closer to the lens or the lens is moved closer to the object, the distance between the focal plane and the lens must be increased to keep the image sharp. When the distance between the lens and the focal plane is not extended as the object is moved closer to the lens, the image of the object becomes blurred or out of focus. Hence, a focused image formed by a lens depends upon two factors: (1) the distance from the lens to the object focused on and (2) the focal length of the lens.

In most types of photography, it is necessary for several objects at different distances to be in sharp focus. This means a compromise because a lens cannot focus directly on several objects at different distances from the lens. If the lens is focused exactly on the far point, the near point is out of focus. The best overall sharpness of both points can be obtained by focusing the lens a little in front of the halfway mark between the near and far points. (See fig. 6-10.)

THE f-VALUE OF A LENS

To use a lens advantageously, the TD must thoroughly understand the relationship between the aperture and the brightness of the image produced at the focal plane.

Relative aperature means the ratio between the effective aperture of a lens and its focal length. The relative aperture of a lens is

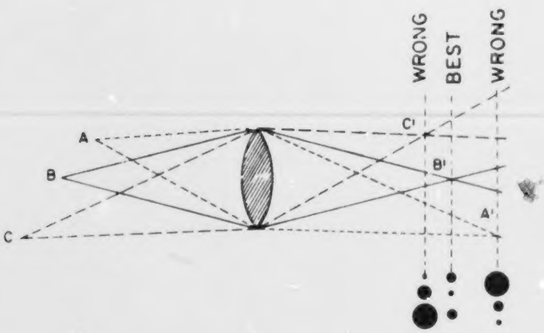


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Figure 6-10.—Focusing in front of the halfway mark.

controlled by two factors: (1) the diameter of the beam of light passed by the lens and (2) the lens' focal length (which governs the size of the area over which the light is spread). The formula for relative aperture is

$$f = \frac{F}{D}$$

Where

f = f/number, or the relative aperture
F = focal length
D = diameter of the effective aperture

EXAMPLE: What is the f/number of a lens if the focal length is 8 inches and the diameter of the effective aperture is 2 inches?

Solution:

$$f = \frac{F}{D} = \frac{8}{2} = 4$$

Therefore, the relative aperture of the lens is f/4.

Arithmetically, the area of a circle varies as the square of its diameter. Photographically, this means that when the diameter of the opening (aperture) in a lens assembly is made smaller, less light is admitted and the image formed by the beam of light passing through the smaller opening becomes dim. Furthermore, as the size of the opening in the lens assembly is reduced, the ratio of focal length to aperture diameter,

$$\frac{F}{D}$$

is increased. This means the f/number becomes larger as the size of the relative aperture becomes smaller.

Focal length is the other factor affecting the brightness of the image formed on the focal plane. Figure 6-11 depicts how changes in focal length affect image brightness.

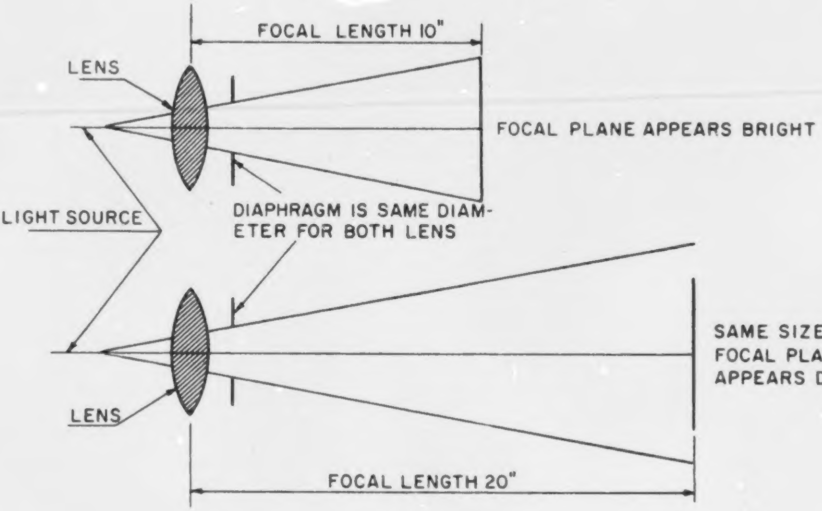
The strength or intensity of the light admitted by a lens varies inversely at the focal plane as the distance the light must travel (from the lens to the focal plane) is squared.

Since the f/number is a ratio of focal length to lens diameter, all lenses having the same f/number, regardless of focal length, should pass the same amount of light on to the focal plane if all the other factors affecting image brightness remain constant.

THE DIAPHRAGM

Each lens assembly contains some mechanical device for controlling the amount of light which passes through the lens. This mechanism may have a fixed-size opening (aperture) or it may be designed to allow a selection from a number of sizes of opening. This device is a diaphragm (or iris) and is frequently called stops. It is located within the lens assembly to cut off or obstruct the marginal rays while permitting the more central rays to pass through the lens. Most lens assemblies contain a series of thin metal leaves for this purpose. These leaves are arranged and shaped to provide an approximately circular opening which can be changed in size when desired. This device, used to form and control the size of the aperture in the lens assembly, is called an iris diaphragm. (See figure 6-12.)

The size of aperture provided by the diaphragm or iris is controlled by moving a ring or lever. If this ring or lever is moved properly, an index mark can be brought into line with one of the numbers indicating a measured f-value of the aperture. As index numbers increase in


FOCAL LENGTH 10"
LENS
FOCAL PLANE APPEARS BRIGHT
LIGHT SOURCE
DIAPHRAGM IS SAME DIAMETER FOR BOTH LENS
SAME SIZE FOCAL PLANE APPEARS DIM
LENS
FOCAL LENGTH 20"

40.162

Figure 6-11.—Image brightness affected by focal length.

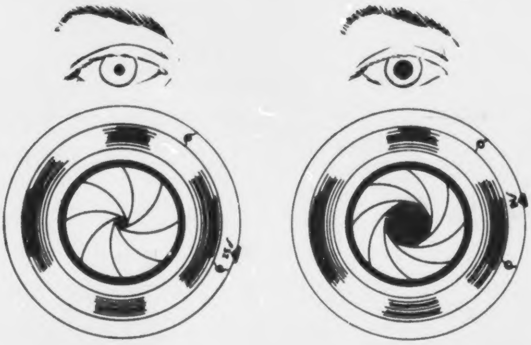


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Figure 6-12.—The iris and iris diaphragm.

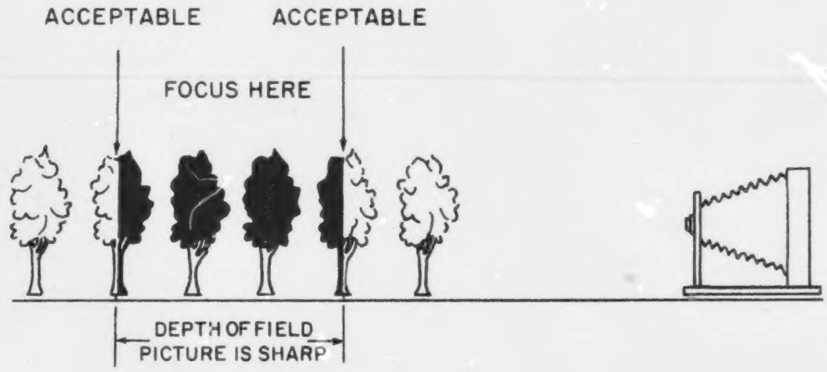
value, the opening decreases in size. These numbers are so chosen that when the index pointer is moved to the next larger number, the amount of light admitted by the iris is cut in half. The first or lowest number in the index number series is usually an exception. All index numbers may not correspond exactly to this ratio, but are sufficiently close for practical purposes. However, the TD will find that the exact variation in all of these values is proportional to the squares of their numbers. For example, f/4 admits four times more light than f/8 because the square of f/4 is contained in the square of f/8 exactly four times.

DEPTH OF FIELD

The hyperfocal distance of a lens is defined as the distance from the optical center of the lens to the nearest point in acceptable sharp focus when the camera is focused on infinity at any given f/number.

The depth of field is the range of distances on the near and far side of the plane focused on within which all objects are in acceptably sharp focus. When the lens is focused at infinity, the hyperfocal distance of the lens is defined as the near limit of the depth of field, and infinity is the far limit of the depth of field. When the lens is focused on the hyperfocal distance, the depth of field is from exactly half that distance to infinity. Figure 6-13 shows a typical depth of field.

The depth of field of a lens is controlled by, and all computations are based upon, the distance focused on and the hyperfocal distance.



40.164

Figure 6-13.—Depth of field.

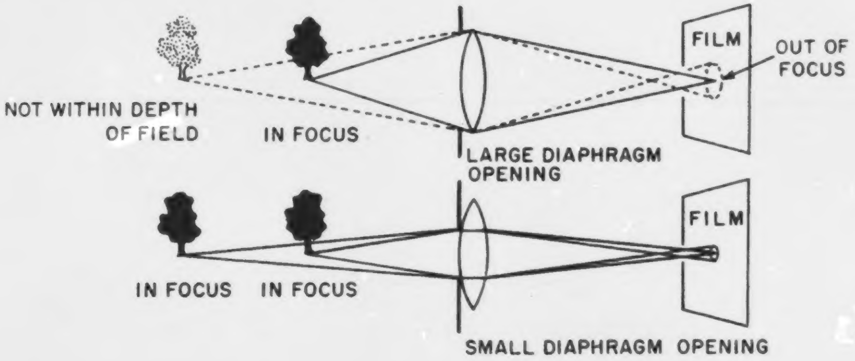
You should recall that the hyperfocal distance of a lens is affected by the focal length and the f/number of the lens. Consequently, the following factors control the depth of field:

1. Focal length of the lens.
2. f/number used (the size of the diaphragm opening).
3. Distance from the lens to the object being focused.

A short focal length lens has a greater depth of field than a long focal length lens. Hence, the shorter the focal length of the lens the greater the depth of field.

Depth of field increases as the lens opening (aperture) is decreased because the size of the cones of light decreases in proportion to the aperture, as shown in figure 6-14.

Physical limitations in the design of lenses, based on the laws of geometry, make it impossible to manufacture a lens having uniform quality and performance from its center to its edges. To obtain the best quality, many manufacturers recommend eliminating use of the lens edge. This is done by using a diaphragm



40.165

Figure 6-14.—Effect of diaphragm on depth of field.

opening about two stops from the largest aperture. This recommended stop, about two full stops below the maximum aperture for a moderately fast lens, is termed the critical aperture or optimum aperture. The critical aperture for a particular lens refers to the stop where the lens renders the best definition. Information on the critical aperture for a lens may be found in the manufacturer's information pamphlet accompanying the lens, or it may be obtained by contacting the manufacturer.

LENS CARE

The lens is one of the most important parts of the camera, since the remainder of the camera unit (or TV equipment) is of little value without the lens. For this reason, the lens should be given considerate and careful treatment. Severe damage to the lens can result from careless handling or improper stowage. By caring for and handling the lens as outlined in the following paragraphs, it should normally outlast the camera unit on which it is mounted.

The glass used in a lens is much softer than ordinary glass. Therefore, the lens cannot be treated like ordinary glass. It must be protected from shock, force, and compression, since any of these will produce great differences in the internal structure of the glass.

The lens barrel should not be forced into its mount nor compressed in any other manner because force and compression will produce changes in the internal structure of the glass.

Perspiration and natural oils from fingers will cause deterioration of the lens surface polish, dimming the image. Keep the lens cap on when not using the lens. This not only protects the surfaces, but will result in less cleaning of the lens.

The lens should not be subjected to chemical fumes, salt spray, excessive heat, steam, or moisture. If the lens becomes exposed to any of the above, it should be given a thorough cleaning before it is stored.

Lenses should never be stored in an excessively warm or damp space. They will remain in good condition if stored in air of average humidity at about 70° F. Lenses should be mounted ready for use, and the storage shelves arranged to hold each lens vertically.

In areas where temperature and humidity are high, lenses should be stored in a dry locker. Each time one is removed for use, it should be cleaned and polished before being returned to the locker. Lenses should also be inspected at regular intervals as a precaution against fungus growth.

Cleaning the Lens

Cover a table with a clean blotter or paper to prevent the possibility of damage to the lens surfaces if they should come in contact with the table. First dust the outer surfaces of the lens with a camelhair brush to remove the larger particles which may scratch the surface. Spray the surface with a recommended lens cleaning fluid and wipe gently with lens tissue, using a circular motion and light pressure.

Treat the outer surface of the other lens element in the same manner, and examine the assembly by looking through it. Further cleaning should not be needed.

MULTIPLEXER

To televise slides, motion picture film, or prepared visual material, a specially constructed unit, called an optical multiplexer (fig. 6-15) is used. One or more motion picture projectors are provided, mounted on a base unit. A drum-type slide projector is also provided. The projectors are aimed at a box containing a system of semimirrors (a reflective surface through which light will also pass). The pickup camera is aimed at the semimirrors, allowing the camera to pick up and transmit pictures from any one projector or any combination of projectors.

A local control unit is mounted on the base unit for operator control of projectors. Control of the multiplexer can be reassigned to a remote station.

The projection of pictures from the projectors to the camera is illustrated in figure 6-16. The light rays from the slide projector (fig. 6-16 (A)) pass straight through the semimirror.

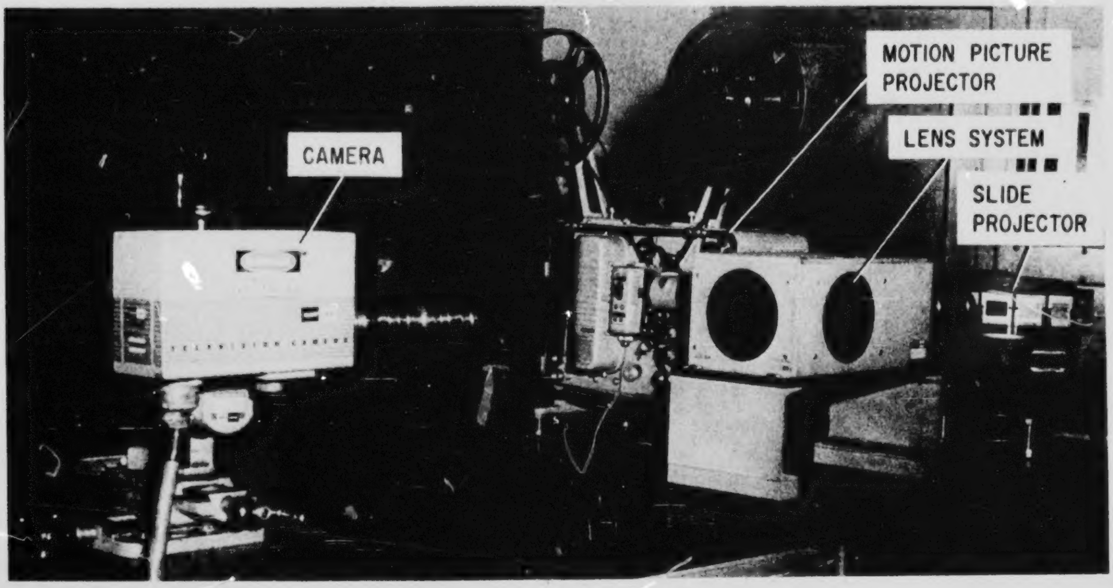


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Figure 6-15.—Optical multiplexer.

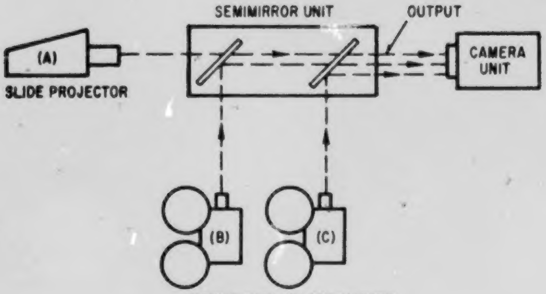

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Figure 6-16.—Block diagram of a multiplexer.

The projection from the motion picture projectors (fig. 6-16 (B) and (C)) is reflected from the semimirrors to the camera.

Variac transformers, located in the base unit, control the illuminating voltage for each projector. Varying the projector lamp illumination is necessary for good reproduction.

CAMERA TUBES

The type of camera tube used is determined by the intended use of the camera and the amount of available illumination. The amount of light required by a camera tube is rated in foot-candles (ft-c). The minimum number of foot-candles required by a camera tube is a measure of the tube's sensitivity.

The following types of camera tubes are used in modern CCTV systems.

VIDICON TUBE

The vidicon camera tube (fig. 6-17) has a transparent conductive coating, called the signal electrode, on the inner surface of the faceplate; a layer of photoconductive material deposited on the signal electrode; an accelerating electrode; a focusing electrode; and a cathode emitter for producing a beam of electrons.

The beam of electrons is directed toward the layer of photoconductive material (on the cathode side of the signal electrode) at a

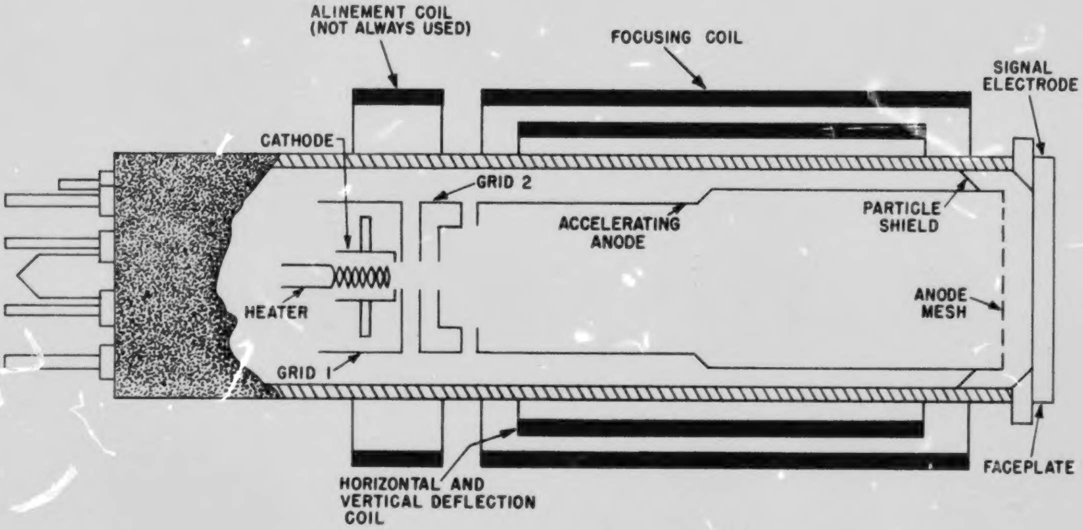

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Figure 6-17.—Structure of vidicon.

medium velocity because of the relatively low accelerating potential between the cathode and the accelerating electrode. A sharp beam is formed by the electrostatic field of the focus electrode and the axial magnetic field of the focus coil surrounding the tube. The electron beam is deflected by the deflection coil in such a way as to scan the photoconductive layer. When no light is permitted to reach this layer, its resistivity is extremely high. One side of the layer is maintained at a small positive potential of 0 to 70 volts by direct contact with the signal electrode.

When light from the scene being televised passes through the faceplate and is focused on the photoconductive layer, the resistivity of this material (which has been extremely high) is reduced in proportion to the amount of light reaching it. Because the potential gradient between adjacent elements in the photoconductive layer is much less than the potential gradient between opposite sides of the layer, electrons from the beam side of the layer leak by conduction to the other side between scans of the electron beam. Consequently, the potential of each element on the beam side approaches the potential of the signal electrode side, and reaches a value that varies with the amount of light falling on the element. On the next scan, the electron stream replaces a number of electrons on each element just sufficient to return it to the potential of the cathode. Because each element is effectively a small capacitor, a capacitive current is produced in the signal-electrode circuit that corresponds to the electrons deposited as the element is scanned. When these electrons flow through the load resistor in the signal-electrode circuit, a voltage, which becomes the video signal, is produced.

Associated with the vidicon tube are the alignment coil, the focus coil, and the deflection coils. The alignment coil produces a magnetic field that is variable in both magnitude and direction and is used to adjust the direction of the electron beam so that it is parallel to the field of the focus coil. Control of the alignment coil current is accomplished in the control unit.

The focus coil surrounds the vidicon tube and establishes a magnetic field along the axis of the tube. It is connected between the +300-volt and the +150-volt power supplies through a resistor located in the rotatable section of the base unit.

The vertical and horizontal deflection coils are excited by linear sawtooth currents from the control unit. These currents produce the field that causes the beam to scan the photosensitive layer.

PLUMBICON

The plumbicon tube is similar in appearance and operation to the vidicon, but has several advantages over the vidicon. The plumbicon tube has a more rapid response and produces high quality pictures at lower light levels. Because of its small size and low power consumption, it is well suited for use in transistorized TV cameras. Its simplicity and spectral response to primary colors make it particularly useful in color cameras.

A unique feature of the plumbicon is that its color response can be varied by the manufacturer. It is therefore available with spectral responses for each of the primary colors. The color response of each tube is identified by the letter R (red), G (green) or B (blue) following its basic number. For example, a plumbicon for a green channel may be designated 55875G.

Principles of Operation

Figure 6-18 provides a simplified diagram of a plumbicon target. The glass faceplate, as shown in (A) of figure 6-18 has its inner surface coated with tin dioxide. This thin, transparent layer is the signal plate of the target. The tin dioxide itself is a strong N-type semiconductor. Two layers of lead oxide are deposited on the scanning side of the target. The first of these two layers is almost pure lead oxide, an intrinsic semiconductor. The second layer of lead oxide is doped to form a P-type semiconductor. As shown in (B) of figure 6-18, the three layers form a P-I-N junction.

Light from the televised scene passes through the layer of tin dioxide and is focused on the photoconductive lead oxide. Note in (C) of figure 6-18 that each picture element charge acts like a capacitor whose positive plate faces the scanning beam. The target signal plate forms the negative plate. As the low-velocity scanning beam strikes each charged element, it releases electrons which neutralize the "capacitors."

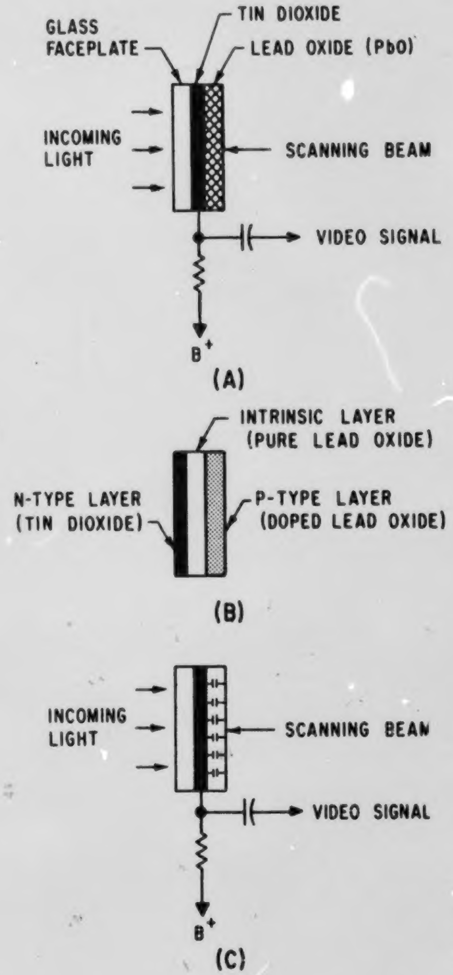

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Figure 6-18.—Plumbicon target.

IMAGE ORTHICON

The image orthicon (fig. 6-19) is an ultra-sensitive television camera pickup tube. The tube requires only 8 to 40 ft-c of light and is used in modern conventional and closed circuit television systems. When this tube is

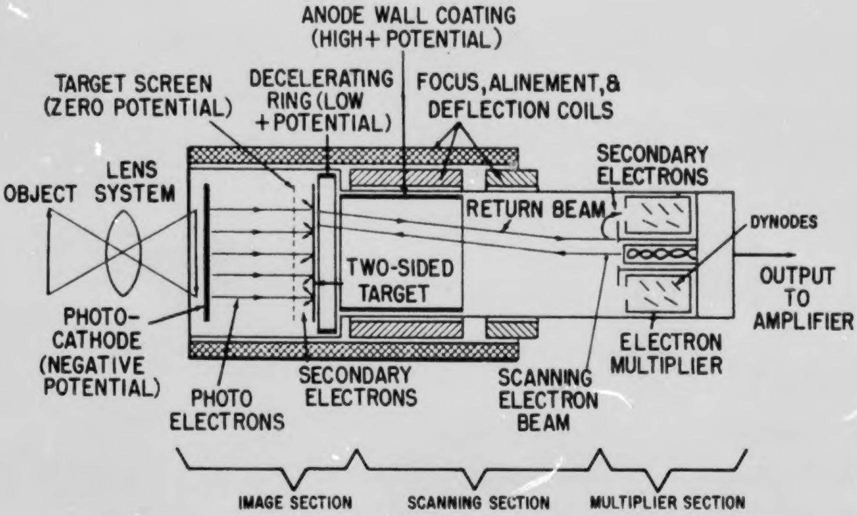

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Figure 6-19.—Structure of image orthicon.

used, a light image from the subject (arrow at extreme left) is picked up by the camera lens and focused on the light-sensitive face of the tube, releasing electrons from each of the thousands of tiny globules in proportion to the intensity of the light striking it.

These electrons are directed on parallel courses from the back of the tube face to the target, from which each striking electron liberates several more electrons, leaving a pattern of proportionate positive charges on the front of the target. When the back of the target is scanned by the beam from the electron gun in the base of the tube, enough electrons are deposited at each point to neutralize the positive charges. The rest of the beam returns, as shown in figure 6-19, to a series of electron multiplier stages or dynodes surrounding the gun.

Each dynode is a metallic disk with openings similar to a pinwheel and operates at a postive potential of 200 to 300 volts greater than the preceding dynode. Multiplication occurs through secondary emission at each dynode. If five dynode stages are employed, each having a gain of 4, a gain of 4 x 4 x 4 x 4 x 4 or approximately 1,000, is realized in the multiplier section. Considering the gain of 5 in the image section, the overall gain of the image orthicon is 5,000, which allows this particular pickup tube to operate with relatively less light than the plumbicon or vidicon. The electrons from the last dynode are routed through a signal-developing resistor to an extremely high B-plus voltage. The output signal is then coupled to the first stage of video amplification.

CAMERA CIRCUITS

The purpose of camera amplifier circuits is to amplify the extremely low output signal from the camera tube. The video signals must be increased in amplitude to overcome tube noise and random circuit noise and hum that may be injected into the video output.

The camera circuits are carefully designed to amplify high- and low-frequency signals equally. The output of the camera tube (fig. 6-20) must be as large as possible. The output circuit contains high resistance, providing good gain at low frequencies but low gain at high frequencies. Because a video signal contains both high- and

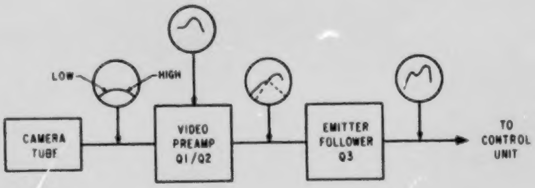

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Figure 6-20.–Typical camera unit block diagram.

low-frequency components, the video stages are designed to amplify more at some frequencies than at others.

BLOCK DIAGRAM ANALYSIS

Video preamplifier Q1/Q2 (fig. 6-20) serves as a "peaker" circuit in that it provides greater amplification to the higher video frequencies. Note that the resultant frequency response curve at the output of Q1/Q2 is reasonably flat over a wide band of video frequencies.

The video signal from Q1/Q2 is routed through emitter follower Q3 and developed across a resistor in the camera control unit. Emitter follower Q3 is used to match the output impedance of the camera unit to the input impedance of the control unit.

CAMERA CIRCUIT ANALYSIS

Video Circuitry

Figure 6-21 illustrates the circuits in a typical camera unit. The vidicon is represented schematically by V1. The elements in a vidicon tube have functions similar to those in an ordinary electron tube; however, the vidicon tube terminology differs somewhat in that the control grid is called the beam control, and the plate the target control.

When the camera circuit is operating, the video signal leaves the vidicon through pin C and is developed across R3. A variable dc focusing voltage is applied to pin 6 of V1 via decoupling network R4 and C2. A fixed positive accelerating voltage is applied from pin 13 of J1, through the contacts of K1, to pin 5 of V1. K1 is normally energized while the camera is operating. (K1 is shown energized.) Vertical blanking pulses and a variable beam control bias are applied from pin 1 of J1 to pin 2 of V1. Pulses from the horizontal deflection yoke are coupled through S2 (shown in normal position), differentiated by C1 and R2, clipped by CR1 and R1, and applied as sharp positive horizontal blanking pulses to the cathode of V1.

Video output from V1 is coupled through C3 to the base of Q1. Q1 and Q2 comprise a compound-connected transistor circuit known as a Darlington amplifier. This type of circuit was selected for use as the preamplifier stage because it has high input impedance, very high current gain, and excellent frequency response. Forward bias for the stage is provided by voltage divider components R6 and R7. R9 and C5 are primarily intended for temperature compensation. The amplified video output from the collector of Q2 is developed across R8 and L1 (a shunt peaking circuit), and coupled through R12 and L2 (a series peaking circuit) to the base of emitter follower Q3. This stage provides an impedance match to allow coupling of the video via coaxial cable to emitter load resistor R26 in the camera control unit.

Vidicon Protection Circuitry

Q4, Q5, and Q6 are used in circuitry designed for vidicon tube protection. Recall from your knowledge of cathode-ray tubes that it is undesirable to allow the electron beam to remain too long on the same spot on the CRT screen. If this occurs or the beam retraces the same line too often, the phosphor-coating on the CRT screen will "burn." A vidicon target is comparable to a CRT screen in that if the vertical and horizontal sweep signals are not present, the vidicon target could become permanently damaged.

Pulsed amplifier Q4 serves to amplify a sampling of the vertical sweep signal which enters the camera on pin 14 of J1. This signal is attenuated by R26 and R25 and coupled through C8 to the base of Q4. After being amplified by Q4, the signal is coupled through C10, rectified by CR2, and filtered by R23 and

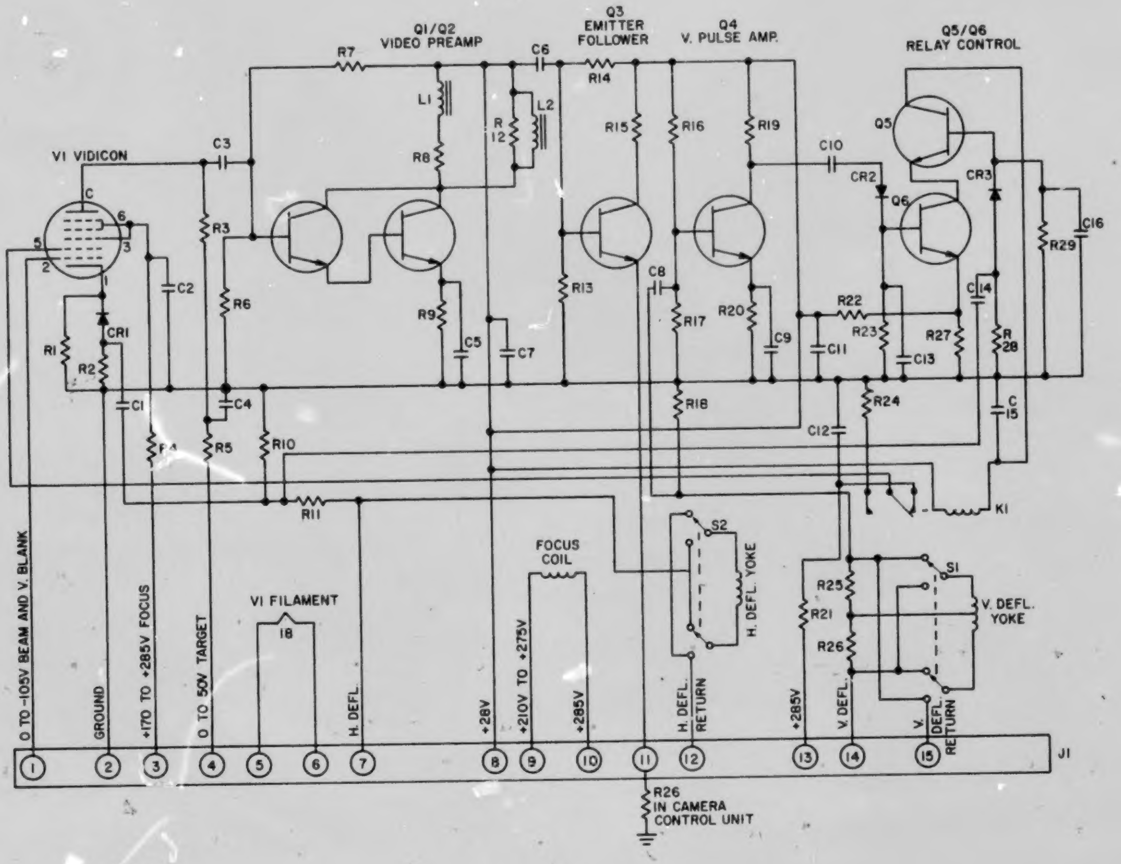

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Figure 6-21.—Typical camera circuit.

C13. The resultant positive dc voltage is used as forward bias for Q6. Note Q6 is connected in series with Q5, forming (in terms of digital computers) an AND gate. To allow current to flow through both Q5 and Q6, forward bias for Q5 must also be provided.

Forward bias for Q5 is developed, logically enough, by action of the horizontal sweep signal, which consists of pulses at 15,750 Hz. This signal enters the camera unit through pin 7 of J1. The pulses are attenuated by R11, coupled through C14 to the anode of CR3, and then rectified. R29 and C16 filter the resultant dc, which is used as forward bias for Q5.

Remember that Q6 is forward biased only as long as a vertical deflection signal is present in the camera unit, and Q5 is forward biased only as long as a horizontal deflection signal is present. Therefore, BOTH the vertical and horizontal deflection signals must be present for current to flow through Q5 and Q6.

Note that the coil of current-sensitive relay K1 is in the collector circuit of Q5. If Q5 and Q6 are conducting, K1 is energized. Look at pin

13 of J1. A +285 volts dc is routed from pin 13 through R21 and the energized contacts of K1 to pin 5 of the vidicon. If the +285 volts dc is NOT present, the vidicon is cut off.

If K1 deenergizes, a ground is applied through R24 to pin 5 of the vidicon tube, assuring that the tube is cut off.

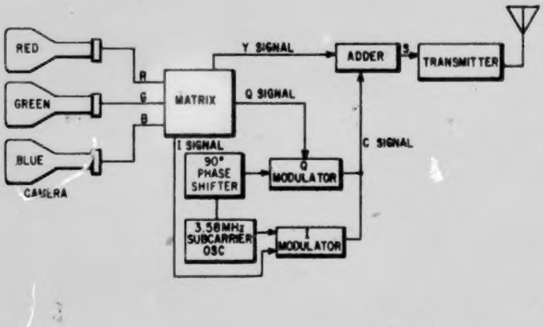
To summarize, if EITHER the horizontal or vertical deflection signal is not present, K1 will deenergize, causing the vidicon to cut off. This provision, of course, serves to protect the vidicon target from being "burned" if sweep signals are lost.

Special Effects

Switches S1 and S2, connected across the vertical and horizontal deflection yokes, respectively, are used to initiate special video effects. Closing S1 causes the image to invert because the direction of current flow is reversed through the vertical yoke. Similarly, closing S2 results in a mirror image because current now flows in the opposite direction through the horizontal yoke.

COLOR CAMERAS

The camera unit used for color pickup is similar to the black and white camera previously discussed. However, in this case the camera unit (fig. 6-22) has three pickup tubes (one for each of the primary colors). Filters and mirrors are used to direct the right color of light to its respective pickup tube. The output of the camera unit provides a red, green, and blue video signal to the matrix system (a circuit which proportions the primary signals to produce the correct brightness and chrominance colors). The three primary colors are identified as R for red, G for green, and B for blue.



40.237

Figure 6-22.—Color TV transmitter block diagram.

The matrix section is essentially a resistive voltage-divider circuit that proportions the primary color signals, as required, to produce the brightness and chrominance signals. With red, green, and blue color video voltages as inputs, the three video signal output combinations formed are the following:

1. A luminance signal, designated the Y signal, which contains the brightness variations of the picture information.

2. A color video signal, designated the Q signal, which corresponds to either green or purple picture information.

3. A color video signal, designated the I signal, which corresponds to either orange or cyan picture information.

The I and Q signals together contain the color information for the chrominance (hue and saturation) signal.

Additional information concerning the color video signal and its transmission will be presented later in this chapter as part of the coverage of the composite video signal.

OTHER CAMERA CIRCUITS

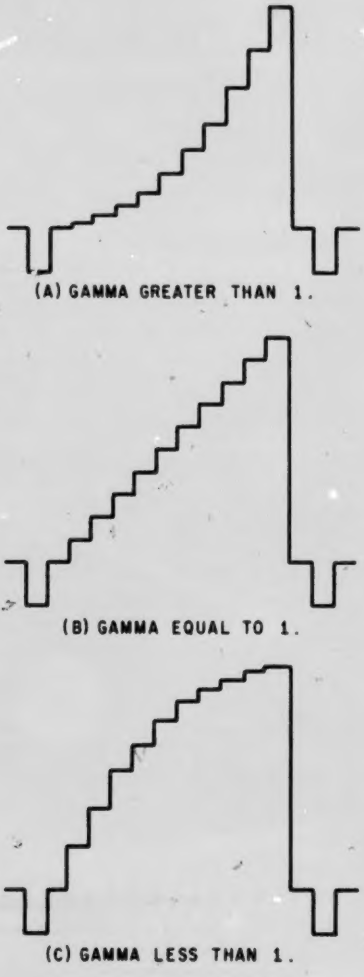
The camera circuits shown in figure 6-21 are reasonably typical, but other circuits are used, too. The following discussion will provide nomenclature for and functions of other circuits used in camera units.

Gamma Correction

Gamma (γ) refers to the transfer characteristic of a camera tube. The gamma rating of a camera tube describes the linearity of the output signal of the tube as compared to that of its input signal. The gamma of a perfectly linear camera tube is 1.

Figure 6-23 illustrates a gamma problem. The stair steps shown represent the video signal, obtained by "shooting" the camera at a linear reflectance chart. The chart itself simply portrays a left-to-right progression of shades from very black to very white.

Figure 6-23 (B) shows perfect linearity through the entire range of shades. (A) and (C) show gammas of greater than 1 and less than 1, respectively.



244.139
Figure 6-23.—Effect of gamma on a linear stair-step signal.

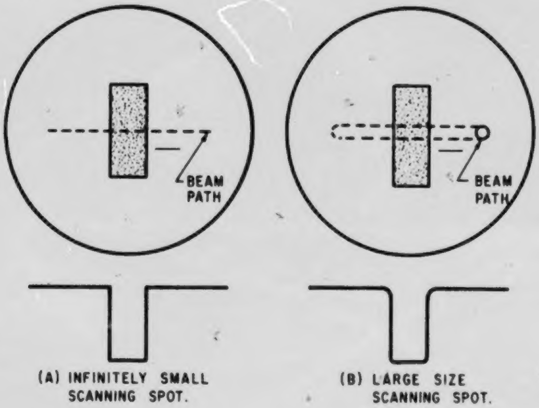
It may seem strange, but a gamma of 1 is not always desirable. For example, if it becomes necessary to compensate for external light falling on the viewing screen, or necessary to improve detail when the area of prime interest is in a dark or light portion of the picture, a gamma other than 1 is used. Gamma correction circuits are sometimes incorporated in the camera unit to provide a means of adjusting gamma.

Aperture Correction

Since the scanning beam in a camera tube has a finite diameter, it follows that if the beam tracks across the image of a vertical bar, the camera tube cannot produce a sharp square-wave output. Figure 6-24 illustrates this difficulty. Obviously, there is no way the detail lost within the diameter of the scanning beam can be recovered, but a round-edged square wave can be resquared. Aperture correction circuits are designed to restore the sharp leading and trailing edges of the video signal. Edge restoration is necessary because the edges represent the small details of picture content.

COMPOSITE VIDEO

The composite video signal contains all the information needed to reproduce the picture. Its


BEAM PATH
BEAM PATH
(A) INFINITELY SMALL SCANNING SPOT.
(B) LARGE SIZE SCANNING SPOT.

244.140
Figure 6-24.—Output waveform of camera tube.

contents include the video from the camera unit, synchronizing pulses to synchronize the transmitter signal with the receiver/monitor, and blanking pulses to obliterate the retrace signals from the picture tube. The video signal is combined with the blanking pulse (fig. 6-25); the sync pulse is placed on top of the blanking pulse.

In the composite video signal, successive values of voltage and current amplitudes are shown against values of time during the scanning of three horizontal lines. During the time when blanking and sync pulses are being transmitted, no video appears. The overall signal amplitude is divided into two parts: the lower 75 percent is for video, and the upper 25 percent is devoted to synchronizing pulses. Standardization is necessary to ensure the transmitted signal is suitable for all receivers/monitors.

The lowest amplitudes correspond to the whitest parts of the picture. The picture becomes blacker as amplitude increases toward 75 percent. This standard of transmission is called "negative transmission," which is defined as decreasing signal amplitude for decreasing light intensities. As the level reaches 75 percent, the grid becomes negative, cutting off the picture tube, and the absence of light establishes the blackest level, which is the case when the blanking level occurs.

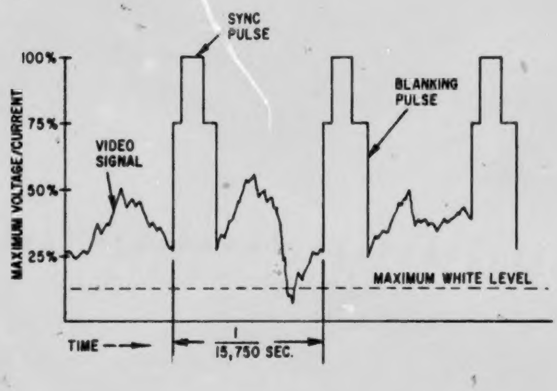


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Figure 6-25.—Composite video signal.

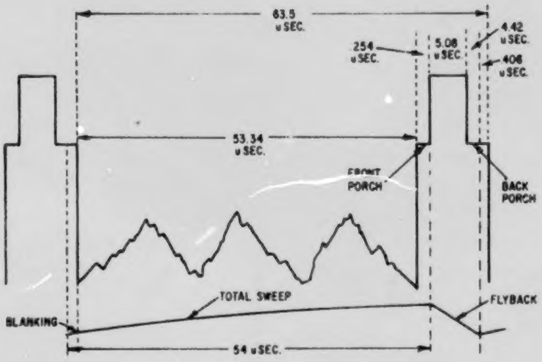

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Figure 6-26.—Composite video time allocations.

Details of the horizontal blanking and sync pulse are shown in figure 6-26. The interval of the complete scan is 63.5 microseconds since the horizontal frequency is 15,750 Hz. The horizontal blanking pulse is 10.16 microseconds, or about 16 percent of total sweep. The sync pulse, superimposed on the pedestal, occupies 5.08 microseconds or one-half the blanking time.

The part of the pedestal just before the sync pulse (0.254 microsecond) is called the "front porch"; the portion following the sync pulse (4.826 microseconds) is called the "back porch." The front porch blanks the right side of the picture screen just before the sync pulse begins. Flyback occurs with the leading edge of the sync pulse and continues for 4.42 microseconds of the back porch. The next sweep starts, but the left side of the screen is blanked for 0.406 microsecond of the starting sweep. This action strives to maintain a straight left edge.

The vertical blanking pulse blanks the picture during retrace time when the electron beam has completed one field and is returned to the top ready to start the next field. Immediately following the last active line, the video signal is brought up to the black level by the vertical retrace.

So far in the discussion little has been said about the special form of the combined synchronizing pulses. The form and the timing of the synchronizing pulses are such that the horizontal and vertical oscillators are triggered at exactly the right instant to keep the sweep in the camera tube and the sweep in the picture tube locked in step. Because the horizontal oscillator must be triggered during the vertical sync pulse (to prevent the horizontal oscillator from drifting out of control), the vertical pulse is serrated, as shown in figure 6-27; that is, the vertical pulse is chopped into six pieces. The fluctuations resulting from serrations do not affect the operation of the vertical oscillator, but serve only to keep the horizontal oscillator properly triggered.

In addition to the serrations in the vertical pulse, equalizing pulses are necessary before and after each vertical pulse. The necessity for equalizing pulses, labeled E in figure 6-27 (B), may be explained as follows:

First, assume that no equalizing pulses are used, as in figure 6-27 (A). If the vertical pulse is inserted at the end of the field, which occurs simultaneously with the end of a full horizontal line (part (1)), the firing potential of the vertical oscillator is reached at the correct time to produce the desired interlaced scan.

If the vertical pulse is inserted at the end of a field, which occurs simultaneously with the end of a half horizontal line (part (2)), the firing potential of the vertical oscillator is reached too early. This is because the slight charge on the capacitor in the triggering circuit of the vertical oscillator (due to each horizontal pulse) does not have time to leak off before the vertical pulse arrives. The residual voltage across this capacitor, plus the voltage due to the vertical pulse, causes the vertical oscillator to fire too soon.

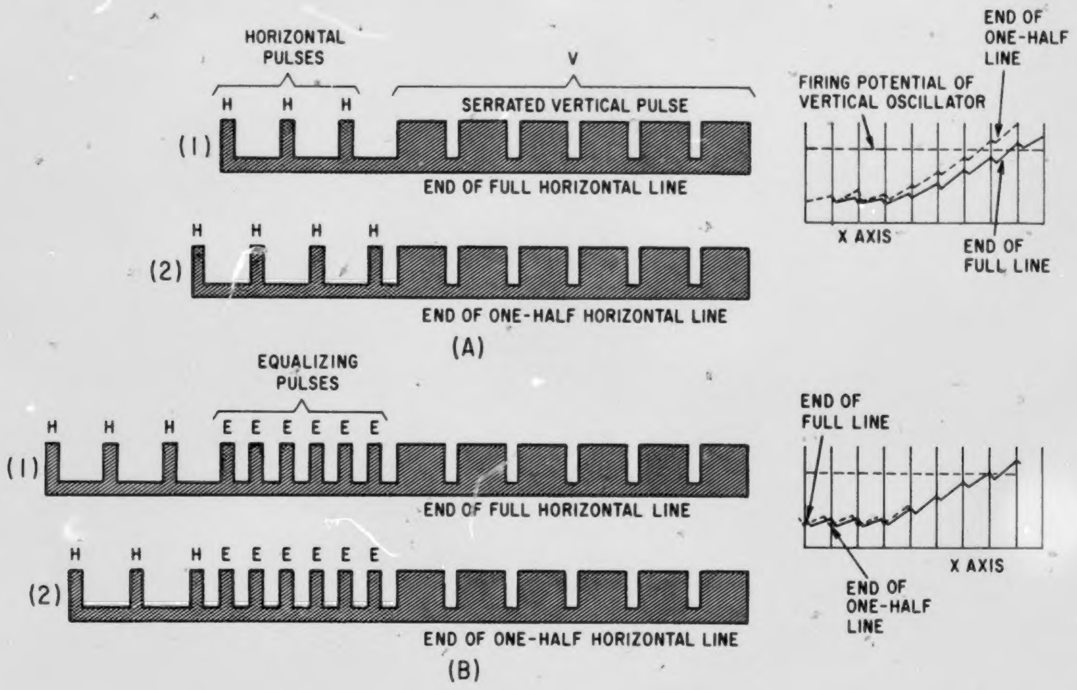

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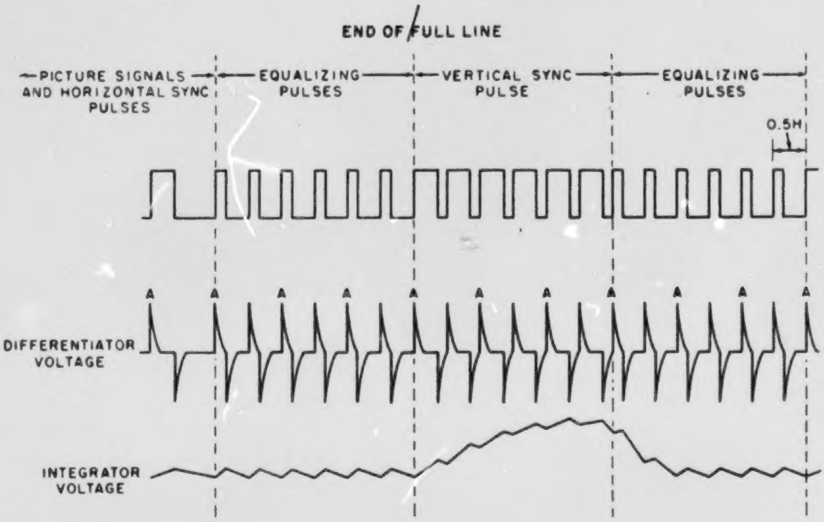
Figure 6-27.—Synchronizing pulse forms. (A) Without equalizing pulses; (B) with equalizing pulses.



7.109

Figure 6-28.—Form of sync pulses comprising the output integrator and differentiator voltages.

Second, the situation is corrected, as shown in figure 6-27 (B), by the use of equalizing pulses. The buildup of the vertical pulse across the capacitor now begins at the same point, whether the vertical pulse arrives at the end of a full line or at the end of a half-line. In other words, the equalizing pulses cause the potential on the capacitor to be at the same level (at the same time the vertical pulse arrives) whether the vertical pulse occurs at the end of a half-line or at the end of a full line. Although not shown in the figure, equalizing pulses are also used after the vertical pulses.

A better idea of the form of sync pulses may be obtained from a study of figure 6-28. It may be seen that a number of horizontal scans are lost during the vertical flyback time.

COLOR VIDEO

Earlier discussion of the color camera revealed that the output signals of the red, green, and blue camera tubes are fed into a matrix and combined to form a luminance (Y) signal and two chrominance (I and Q) signals. We will now discuss how these signals are used to form the COLORPLEXED COMPOSITE VIDEO signal.

The output signal from the red camera tube consists of two components: (1) a signal representing the color red called the chrominance or R signal, and (2) a signal representing the video brightness level on a black-to-white scale, called the luminance or Y signal. To obtain chrominance (or color) information alone, it is necessary to subtract the luminance component. Thus, the red chrominance signal is equal to R - Y. Similarly, the blue chrominance signal is equal to B - Y, and the green chrominance signal is equal to G - Y.

The luminance (Y) signal modulates the video carrier and is transmitted the same as a monochrome video signal. A monochrome TV set receiving a colorplexed transmission reproduces the Y signal for black and white display on the TV screen. The luminance (Y) signal is transmitted within the alloted 4-MHz video bandwidth (disregarding the 1.25 MHz vestigial sideband). Although the luminance signal stretches across the band, it does not completely fill it. Actually, the video clusters about the horizontal scanning pulses (15,750 Hz and its harmonics). Notice in figure 6-29 that there are spaces between the clusters of video

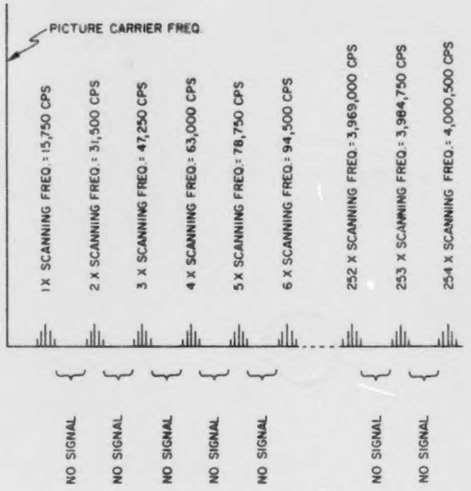


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Figure 6-29.—Distribution of video in the 4-MHz video band.

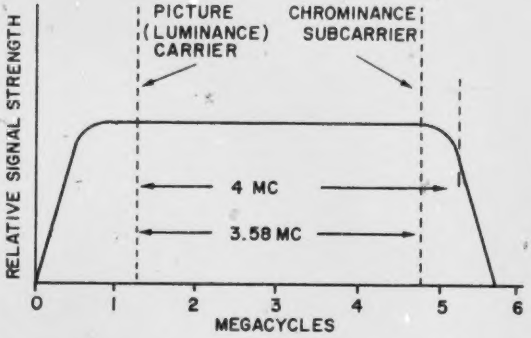

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Figure 6-30.—Locations of the luminance carrier and the chrominance subcarrier in the video band.

data. It is not indicated in figure 6-29, but the chrominance information is interleaved in these spaces. This is accomplished by modulating a subcarrier whose frequency is 3.58 MHz higher than the video carrier. Figure 6-30 illustrates the relationship between the chrominance (or chroma) subcarrier and the luminance carrier. The chrominance (R, G, or B) signal must convey two trains of data: saturation data and hue data. This problem is solved by generating two subcarriers, equal in frequency but differing in phase by 90°. These subcarriers are the I (in-phase) and Q (quadrature) signals mentioned earlier.

The two subcarriers are then suppressed, eliminating beat interference (at 920-kHz) between the chroma subcarrier (3.58 MHz) and sound carrier (4.5 MHz). Thus, a chroma subcarrier has been developed at 3.58 MHz, varying in both amplitude and phase. The amplitude variations represent saturation and the phase variations represent hue. Figure 6-31 shows how different colors affect the phase of the chroma signal.

Fairly coarse picture detail (video frequencies between 0 and 0.5 MHz) requires the full array of signal data (hue, saturation, and luminance). Since the eye loses its ability to distinguish chrominance differences as the picture detail becomes finer, only the Y and saturation signals are used to produce video in the 5- to 1.5-MHz range. When viewing very fine picture detail corresponding to video frequencies of 1.5 MHz and higher, the eye cannot perceive color, so only the Y (luminance) signal is required. Figure 6-32 shows a graphic representation of a color TV channel, including location of the I and Q signal sidebands.

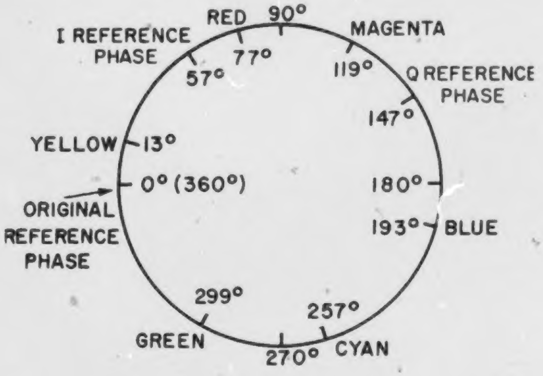

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Figure 6-31.—How different colors affect the phase of the signal.

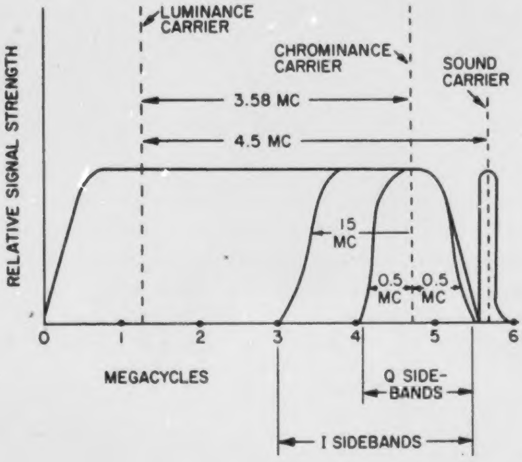

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Figure 6-32.–Graphic representation of the color television channel, showing the location of the I and Q sidebands.

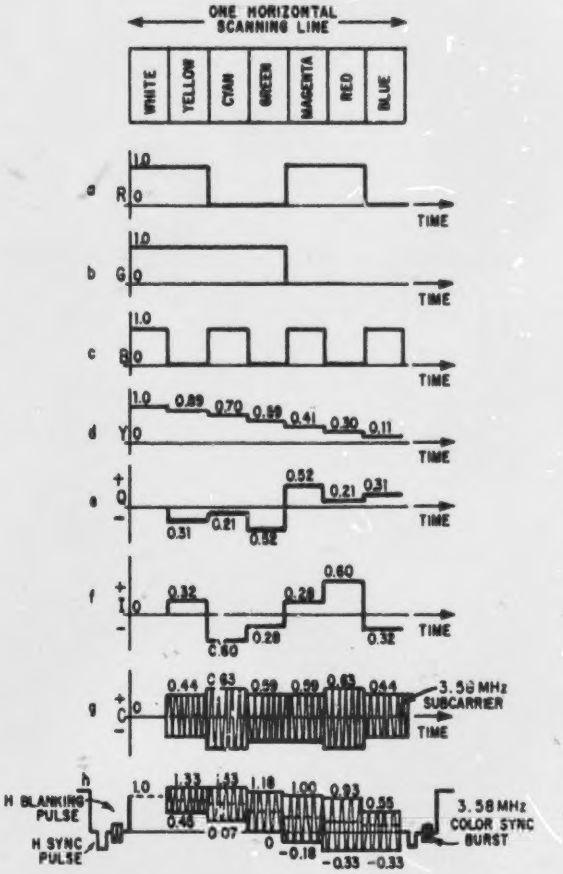

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Figure 6-33.–Colorplexed composite video signal.

Examination of figure 6-33 will reveal how the combination of color signals develops the proper hues of colors.

Figure 6-33 illustrates the scanning of one horizontal line as well as the colors being developed. The signals developed under the white section can readily be seen by following down the column. Adding one unit of R, G, and B together, produces the maximum Y (1.0) signal. This results in zero Q, I, and C signals; further resulting in a transmitting signal level of 1.0.

To develop yellow, one unit of red (30 percent) plus one unit of green (59 percent), develops a Y signal of 0.89 (89 percent). Before computing the Q signal, a different set of values for the units of red, green, and blue are established as follows:

1. One unit of red equals 21 percent.
2. One unit of green equals -52 percent.
3. One unit of blue equals 31 percent.

Referring to the yellow column of figure 6-33, it can be seen that one unit of red (21 percent) plus one unit of green (-52 percent) plus no blue develops a Q signal of -0.31. The following set of values is established for computing the I signal:

1. One unit of red equals 60 percent.
2. One unit of green equals -28 percent.
3. One unit of blue equals -32 percent.

The amount of I signal developed for the yellow column is computed: one unit of red (60 percent) plus one unit of green (-28 percent) plus no blue develops an I signal of 0.32.

The chrominance signal C (g, fig. 6-33) is the 3.58 MHz subcarrier modulated by the I and Q signals which are in quadrature (out of phase) with each other. Combining the Y, I, and Q signals with blanking and sync pulses produces the colorplexed video signal (h, fig. 6-33). Also inserted on the "back porch" of the blanking pedestal, is a synchronizing 3.5-MHz color burst. The color burst synchronizes the receiver's color circuits with the transmitter subcarrier frequency.

CONTROL UNIT

Refer again to figure 6-2 and locate the control unit block.

Sync generators in this control unit, function to provide reference signals to keep the scanning signals in the monitor in-step with those in the camera.

Another function of the control unit is to maintain a stable phase relationship between the vertical and horizontal scanning signals. If the phase relationship between these signals is allowed to vary, the 2:1 interlaced scan will not be stable.

To obtain the required phase lock, both the horizontal and vertical sync signals are generated in a common master oscillator, then converted by use of appropriate count-down circuits to signals having the required frequencies.

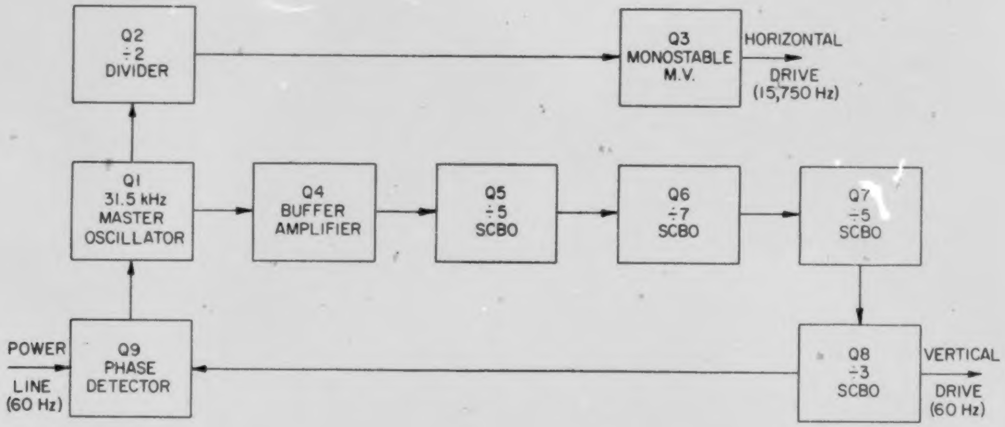
BLOCK DIAGRAM

Figure 6-34 shows the block diagram of a typical pulse-counter type of sync generator. Master oscillator Q1 generates the 31.5-kHz signal from which both the horizontal and vertical drive signals (which will later become sync signals) are derived.

The frequency and phase of the master oscillator signal are stabilized by phase detector Q9. This stage compares both the frequency and phase of the vertical drive signal with those of the 60-Hz power-line reference signal. The power-line frequency is maintained within very close tolerances by the local electric company.

Frequancy divider Q2 serves to halve the master oscillator frequency to 15,750 Hz. This signal is used to trigger Q3, the horizontal-drive multivibrator.

Buffer amplifier Q4 is an isolation stage used to shield the master oscillator from the loading effects of Q5, a single-cycle blocking oscillator (SCBO). Q5 is the first of four count-down circuits (Q4, Q6, Q7, and Q8) used to produce



244.145

Figure 6-34.—Sync generation using pulse counters.

the 60-Hz vertical drive signal. Note that Q8 has two output signals, one of which is the vertical drive signal. The other output signal is routed back to phase detector Q9 where (as stated before) its frequency and phase are compared with those of the 60-Hz power-line reference voltage.

The vertical and horizontal drive signals are then routed from the sync generator to sync insertion circuits in another section of the control unit.

SYNC GENERATOR CIRCUITS

Sync generators usually consist of only a few basic circuits, with these circuits being repeated in different areas. Simplified versions of some of the more common sync generators will now be described. For information on sync circuits not discussed here, refer to *Basic Electronics*, NAVEDTRA 10087 (Series).

Master Oscillator

Figure 6-35 shows a simplified schematic of a 31.5-kHz master oscillator, in which Q3 is connected to form a modified Armstrong oscillator circuit. The frequency of this free-running master oscillator is determined by the values of C6 and T1. The inductance of T1 can be changed by adjusting the position of its movable core.

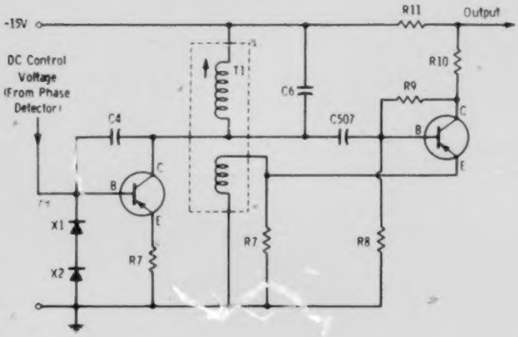


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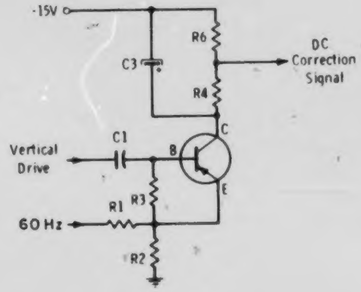
Figure 6-35.—Master oscillator.



244.147

Figure 6-36.—Phase detector.

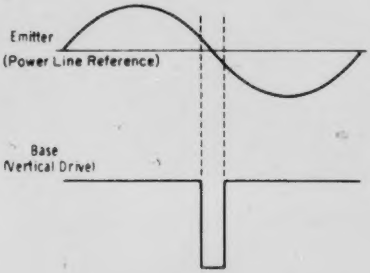
Q2 and associated circuitry comprise a reactance stage capable of changing the master oscillator frequency as a function of the dc control voltage applied to the base of Q2. The dc control voltage is the output of the phase detector previously discussed in the block diagram analysis.

REACTANCE STAGE ANALYSIS.–In general, if the output signal of an amplifier can be made to lead or lag the input signal, that amplifier can function electrically as a variable capacitor. Refer again to figure 6-35 and imagine Q 2 and associated circuitry to be a variable capacitor in series with C6. C4 and varicap diodes X1 and X2 form a capacitive voltage divider in the feedback loop of Q2. Being capacitive, the feedback loop causes the correction signal voltage to lag the signal current in the loop. The degree of lag is proportional to the amplitude of the correction signal. The apparent change in capacitance "tunes" the master oscillator to the "desired" frequency.

Phase Detector

Figure 6-36 shows a phase detector circuit such as used to provide a dc correction voltage to the reactance stage previously discussed, and shown in figure 6-35.

Note in figure 6-36 that a vertical drive signal is fed to the base of Q1 and a 60-Hz ac



244.148
Figure 6-37.—Phase relationships in the phase detector.

reference signal is fed to the emitter. Q1, which is normally cut off, is brought into conduction by the vertical drive signal (consisting of negative pulses). The normal phase relationship between the vertical drive and the 60-Hz reference signals is shown in figure 6-37. As long as a vertical drive pulse appears when the reference signal passes through zero, a "normal" control voltage will be produced. If, however, the normal phase relationship tends to drift, a larger or smaller correction voltage will be produced. C3 in the collector circuit acts as a filter capacitor, ensuring that a smooth dc correction voltage is applied to the reactance stage.

Frequency Divider

A single-cycle blocking oscillator (SCBO) circuit is often used as a frequency divider circuit (or countdown circuit) in sync generators. An example is shown in figure 6-38. In this circuit, Q9 is normally cut off. Input pulses from a preceding stage gradually build up a charge across C17 until a forward bias condition is achieved. As Q9 begins to conduct, a regenerative signal is coupled through T2 to the base of Q9. This regenerative signal causes Q9 to reach saturation rapidly. As soon as Q9 saturates, C17 discharges through the transistor. When C17 discharges sufficiently, Q9 abruptly stops conducting. The collapsing field around the secondary of T2 assists in driving Q9 into sharp cutoff. Diode X6 swamps T2, suppressing resonance oscillations. The values of C17, R31, and R30 have been specially chosen to allow the transistor to conduct when the appropriate number of input pulses has been applied. Figure 6-38 shows appropriate values for a 5:1 countdown.

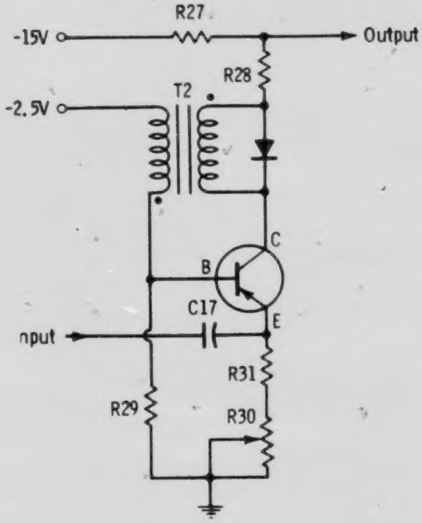


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Figure 6-38.—Blocking-oscillator frequency divider.

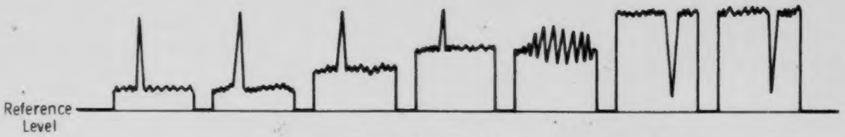
SYNC AND BLANKING INSERTION

Our earlier discussion of camera circuits revealed that the video signal is developed in the camera tube and routed through the video amplifier and peaking circuits to the control unit. After entering the control unit, the video signal is subjected to additional amplification and peaking. Video from the camera tube is referred to as "raw" video, that is, no sync nor blanking signal is included. It is therefore necessary to insert the sync and blanking signals to produce a composite video signal.

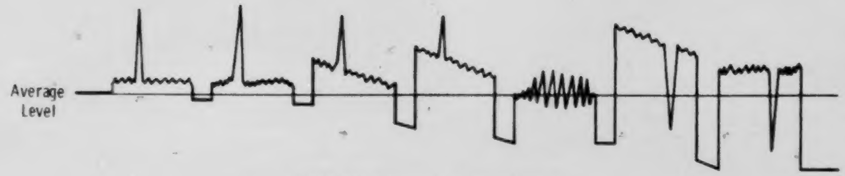
Sync and blanking insertion is often performed in the control unit. Typical insertion circuits are discussed below.

Blanking Insertion

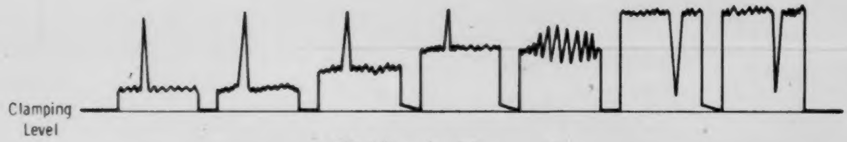
Blanking signal insertion is most often performed before sync signal insertion. Before



(A) Original waveform.



(B) After capacitive coupling.



(C) After clamping.

244.150

Figure 6-39.–Clamping waveforms.

the blanking signal can be inserted, the proper dc reference level must be established by clamping circuitry.

Clamping is needed because a coupling capacitor cannot pass dc, and also has difficulty in passing low-frequency ac signals. Note in figure 6-39 that the RC-coupled signal assumes an average level varying about the bias voltage level of the preceding stage.

Keyed clamper circuits are used in most of the modern CCTV systems. Consequently, no clamping occurs unless a keying pulse is present. Typically, the horizontal drive signal is used as a keying pulse.

Figure 6-40 illustrates a blanking insertion circuit. In this circuit, Q8 is forward biased each time a clamping pulse (horizontal drive pulse) is applied to its base.

When Q8 conducts, the video signal is clamped at the blanking level established by R31. The clamped signal (video) is applied to the base of emitter follower Q9, amplified, and directly coupled to the base of Q10, the blanking mixer stage. Note that the level of forward bias for Q10 is determined by the potential at the emitter of Q9 which is itself controlled by adjustment of R31. The blanking signal is therefore clipped (limited) by Q10 at a

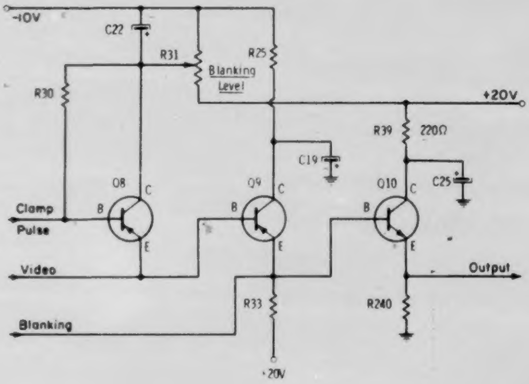


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Figure 6-40.–Blanking-insertion circuit.

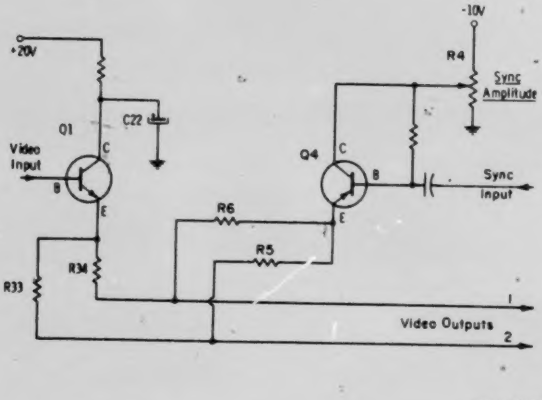

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Figure 6-41.—Sync-adding network.

level established by R31. The output of this stage is routed to a sync insertion circuit.

Sync Insertion

The sync signal is normally inserted into the composite video signal after the blanking signal has been inserted. The sync insertion circuit used is generally a simple additive mixer similar to the sync-adding network shown in figure 6-41. In this network, sync is added (via R5 and R6) to the video signal at the video output terminals.

Isolation amplifier Q4 prevents the coupling of video to the sync input terminals. Adjustment of potentiometer R4 sets the gain of Q4, thus controlling the sync signal amplitude. Transistor Q1 is the video-output stage.

CHAPTER 7

CLOSED CIRCUIT TV: RECEIVERS, MAINTENANCE AND APPLICATIONS

This chapter continues the discussion of CCTV with an in-depth look at TV receivers, CCTV system analysis, and the application of CCTV systems to training devices.

Figure 7-1 is a sectional block diagram of a TV receiver. Each of the major sections will be discussed.

TELEVISION TUNERS

Television tuners, like those of communications receivers, consist essentially of three parts: the RF amplifier, the oscillator, and the mixer. The function of the tuner, often called the front end, is to amplify the relatively weak input signal, to produce a locally generated RF signal, and to mix these two signals in such a way as to produce signals at the chosen audio and video intermediate frequencies. Because of the wide band of frequencies (approximately 6 MHz) that must be passed, overcoupling and loading are employed to increase the frequency response.

A block diagram of a typical front end is shown in figure 7-2. A number of different

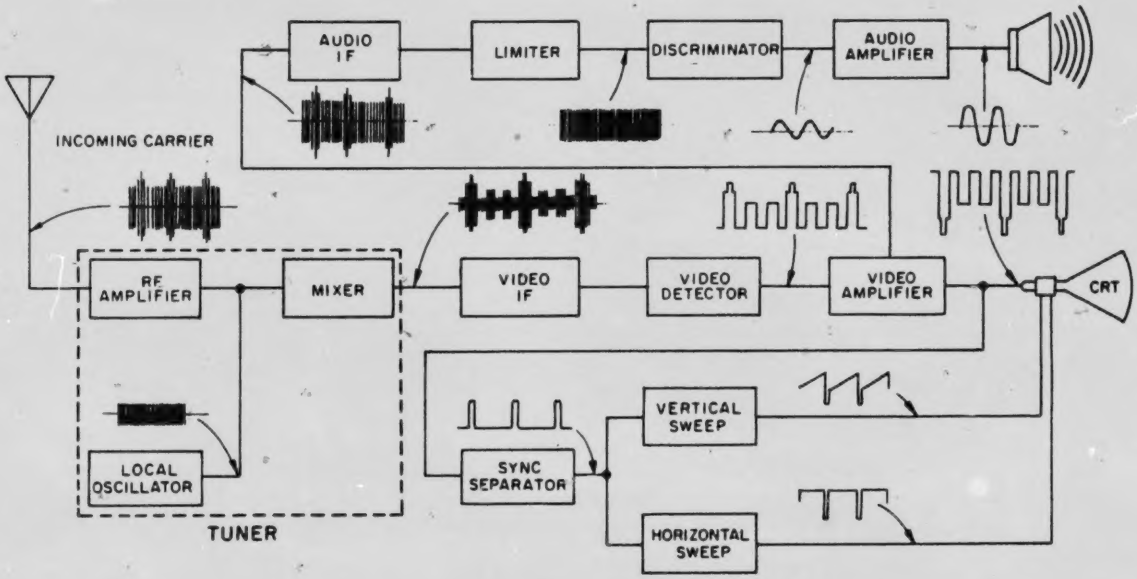

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Figure 7-1.—Sectional block diagram with waveforms.

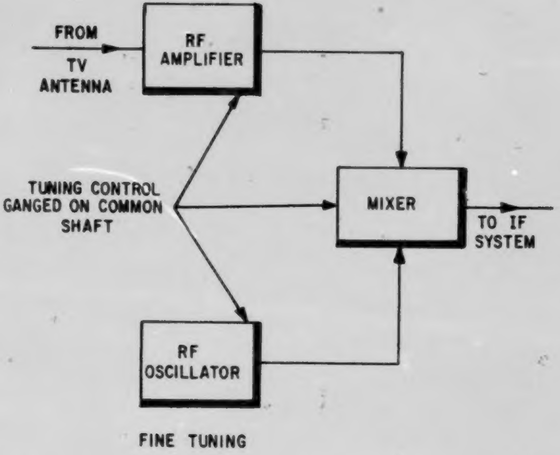

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Figure 7-2.—Block diagram of TV front end.

methods of tuning are employed by television receiver manufacturers and, consequently, many different types will be encountered by the Tradevman. Rotary switches that connect the correct capacitors and inductors into the circuit are often employed. In some systems the "tuned line" is used, and in others separate components are connected for each channel. Turret tuners are also widely used. In this system of tuning, elements pretuned to the desired frequency may be plugged into a clip in the turret. For compactness and precision, printed circuits are sometimes employed.

Although certain problems are involved in continuous tuning, various forms of continuous tuners are used in a number of sets. The Inductuner, produced by the Mallory Company, is a popular tuner in which the inductance is varied over the tuning range while the capacitance remains constant.

RF AMPLIFIERS

Because the television signal available at the input of the television receiver is weak, it is desirable to amplify the signal in a stage of RF amplification before it is applied to the mixer.

Various types of RF amplifiers employed in TV receivers include common emitter, pentode, and FETs, all of which are discussed in detail in *Basic Electronics Vol. 1*, NAVPERS 10087-C. The FETs are finding extensive applications in television because of the advantages discussed below.

Advantages of Field-Effect Transistors

In an ordinary transistor, current flow through the device is dependent upon both the hole flow and the electron flow. Since both polarities of the charges are required for their operation, ordinary transistors are sometimes referred to as bipolar devices. In comparison an FET is an unipolar device, because the flow of current through it is either by hole flow or electron flow, but not by both. Since an electron-hole combination causes noise, a unipolar device generates less noise in its operation. This is a definite advantage in RF amplifiers.

Another advantage of FET operation is its high input impedance. In this regard it is similar in operation to the vacuum tube. Unlike transistor amplifiers which require current flow in the base circuit, and therefore require input power, an FET circuit may be designed that has virtually no current flow in the gate circuit.

The third advantage of the FET is its square law operation. Current flowing through the FET is directly proportional to the square of the voltage on the gate, which means it is a square law device rather than a linear device.

FET-RF Amplifier

Figure 7-3 shows a typical (simplified) circuit with a dual-gate FET used as an RF amplifier. An AGC voltage is developed across a voltage divider comprised of resistors R_1, R_2, and R_3. Capacitors C_1 and C_2 filter the AGC voltage so that only a dc voltage is applied to the gates. The largest part of the AGC voltage is applied to gate G_2.

The RF signal from the antenna is applied through C_3 and developed across R_3. This signal voltage appears on gate G_1. Thus, the amount of current through the FET is controlled by two voltages: the AGC voltage and the RF input voltage. The source bias is supplied by R_4, and

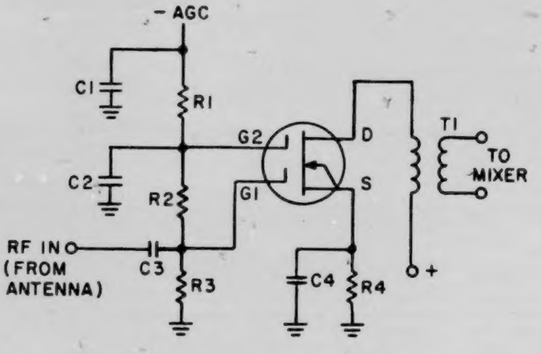

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Figure 7-3.–Dual gate MOSFET RF Amplifier.

C_4 is used to prevent degeneration. The output signal is taken from the secondary of transformer T_1 and fed to the mixer stage.

OSCILLATORS

Local oscillators provide a signal that is heterodyned in the mixer with the RF signal. As in the case of superheterodyne radio receivers, the local oscillator frequency is normally above the incoming RF frequency by a frequency that is equal to the receiver IF frequency.

The local oscillator frequency is changed whenever the channel selector is changed/tuned from station to station. The fine-tuning control varies the oscillator frequency over a narrow range. The setting of the fine-tuning control is very important if a satisfactory color picture is to be obtained.

One of the most frequently used tube type oscillators is the ultra-audion; the Colpitts oscillator is a popular transistorized oscillator. Since oscillators are covered in detail in *Basic Electronics Vol. 1*, NAVPERS 10087 (Series), this information is not repeated here.

MIXERS

As shown in figure 7-2, the mixer receives a signal from both the RF amplifier and the oscillator circuits and converts these to a different frequency output, called the intermediate frequency (IF) signal. This conversion is accomplished by applying both the RF and oscillator voltages to a nonlinear amplifier. If the amplifier is nonlinear, heterodyning will take place, and the output signal will include both the sum and difference frequencies, as well as the two original frequencies. Assuming the frequency difference between the RF and oscillator signals is appreciable, a selective network tuned to the lower frequency component of the output will pass the desired IF only.

The dual-gate MOSFET makes an ideal mixer amplifier. This type of transistor was shown in figure 7-3. Recall it had two gates for inputs. One of the gates could be used for the RF input and the other for the oscillator input, or both inputs can be delivered to one gate, and the other used as a screen to isolate the input and output stages of the mixer. Mixers are also discussed in *Basic Electronics*.

SOLID-STATE TUNING

A more recent development in television tuners is the solid-state tuning system. The solid-state tuning system is based upon the use of the "varactor" diode. This diode is also known by the name voltage-variable capacitor, and by the trade names, Varicap and Selicap. The varactor is a special solid-state diode (special doping) that acts as a capacitor whose capacitance varies inversely with the amount of reverse bias applied across the diode. All vacators operate only with a reverse bias. The tuned circuits to which the varactor is connected have their resonant frequency changed merely by changing the amount of reverse bias across the varactor. The greater the reverse bias across the varactor the less the varactor capacitance and the higher the tuned-circuit resonant frequency.

Figure 7-4 is a simplified drawing of a varactor controlled tuning circuit. In actual practice, the switch (SW) would have positions (and respective variable resistors) for each of the VHF channels. In order for the varactor to control the frequency of the tuned circuit, it is placed across variable capacitor C_2. The amount of reverse voltage on the varactor is controlled by the switch position and the setting of the

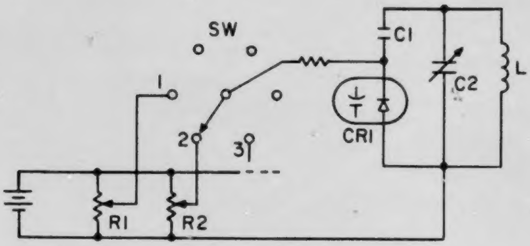

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Figure 7-4.—Varactor controlled tuning circuit.

variable resistors. Capacitor C_1 is an isolation capacitor used to prevent dc current flow through L.

In actual practice, it is not possible to get a varactor diode to provide a complete capacitor range for tuning all VHF or UHF stations. Therefore, it is common practice to switch in a different inductor for the upper VHF channels.

VIDEO IF AMPLIFIERS

Video IF amplifiers perform essentially the same functions that are performed by the IF amplifiers in superheterodyne radio receivers. However, bandpass considerations, vestigial (pertaining to a remnant or remaining part) sideband transmission, the necessity for trapping unwanted sound and video beat frequencies, and other factors make the design of video IF amplifiers somewhat complex. A detailed discussion of the various types of video IF amplifiers will not be presented; however, the overall problems and some of the methods used to solve them are given.

Perhaps the best approach is to list the various problems inherent in the video IF section of a television receiver, and indicate one or more methods of solving each of the problems.

FIRST: For RF spectrum economy, the lower video sideband is greatly suppressed, and the video information is contained largely in the unsuppressed upper sideband. The remaining portion of the lower sideband is the vestigial sideband. The general form of the television RF spectrum was shown in chapter 6, figure 6-1.

Because it is impracticable to remove all of the lower sideband, the response curve of the video IF stage must have a special form. In general, the response curve is similar to that shown in figure 7-5. It may be seen that the video IF has a higher frequency than that of the incoming signal.

That portion of the sidebands extending 1.25 MHz on both sides of the video carrier contains more energy than the sidebands beyond 1.25 MHz (chapter 6, fig. 6-1). This results from the fact that both upper and lower sidebands exist in the 1.25 MHz bandwidth in the immediate vicinity of the video carrier; whereas, beyond 1.25 MHz only the upper sideband is present. If the IF amplifiers were flat over the video band, the frequencies between 0 and 1.25 MHz on each side of the video carrier would be overemphasized at the second detector. In other words, the amplitude of these signal frequencies would be greater than that of the remaining frequencies in the upper sideband of the video signal because of the increased energy associated with the frequencies between 0 and 1.25 MHz on each side of the video carrier.

In order to achieve uniformity in the magnitude of the output video signal for all frequency components, the IF stages are adjusted so the video IF carrier falls about halfway down on the upper slope of the response curve. The lows are therefore amplified less than the highs, and a more uniform response is achieved. For example, a receiver tuned to channel 3 having a video carrier of 61.25 MHz may have a local oscillator frequency of 107 MHz. The IF bandwidth will then extend from 107-61.25 = 45.75 to 107-65.25 = 41.75, or a total of 45.75-41.75 = 4 MHz. In the alignment of video IF stages, this adjustment is very important.

SECOND: Because the response characteristic of the RF and converter stages is intentionally broadened to pass the desired range of frequencies (6MHz), the sides of the response curve taper off gradually. This means that undesirable frequencies may be passed

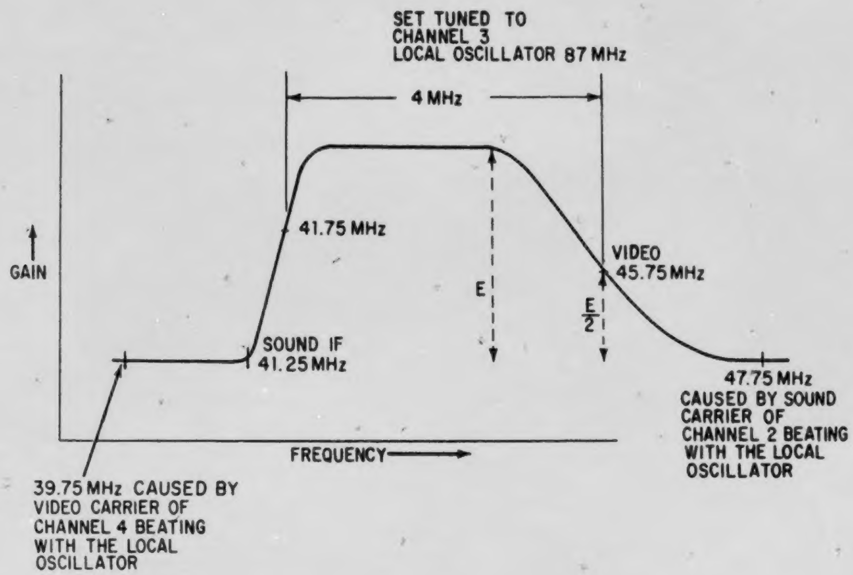

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Figure 7-5.–Video IF response curve.

through to the video IF system, which may cause horizontal bars to appear on the picture. For example, it is assumed that a television receiver employing a split-sound system is tuned to channel 3. (In a split-sound system, the audio is taken off before the detector stage; whereas, in intercarrier-sound systems, the audio is taken off after the detector stage.) The frequencies (39.75 MHz, 41.25 MHz, and 47.75 MHz) that may cause trouble on the television screen are indicated in figure 7-5. The 39.75 MHz beat note, caused by the combining of the video carrier (67.25 MHz) of channel 4 with the local oscillator frequency (107 MHz), is close enough to the desired frequencies to be passed through to the video IF system. Likewise, the 47.75 MHz beat note, caused by the combining of the sound carrier (59.75 MHz) of channel 2 with the local oscillator frequency (107 MHz), is close enough to be passed also. Of course, the sound IF (41.25 MHz) of channel 3 is the signal most likely to get through and must be trapped out. In intercarrier systems, this frequency, which beats with the video IF to produce the 4.5 MHz sound IF, must not be removed until after the sound IF (4.5 MHz) has been fed to the audio channels.

TRAPS

Basically, there are five types of traps used in conjunction with video IF amplifiers. These traps are known as series, parallel, absorption, degenerative, and bridged-T and, for the most part, are used in both vacuum tube and solid-state circuits for either monochrome- or color-TV reception. The bridged-T trap is the most widely used circuit and is indispensable in color-TV receivers.

The series trap is a parallel resonant circuit configuration, figure 7-6(A). It is placed between two IF stages and tuned to the frequency to be rejected. This type of trap circuit is a sharply tuned network designed to reject one frequency or, at most, a narrow band of frequencies. When a signal voltage at the trap frequency appears at the input of the circuit, the impedance offered by LC is very high and almost all of the undesired voltage is dropped across the trap network. A negligible amount of

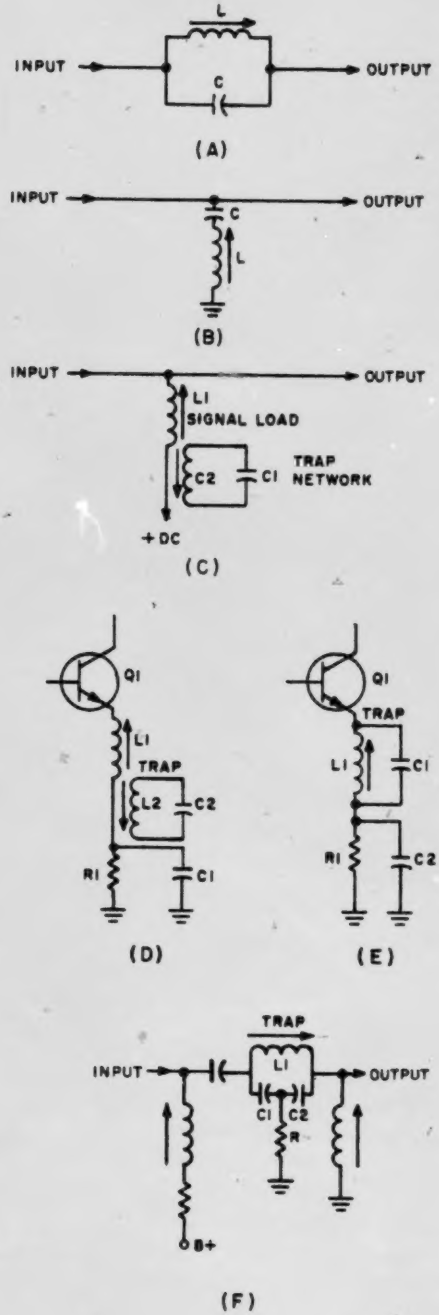

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Figure 7-6.—Trap circuits.

the voltage appears across the input circuit of the following IF amplifier. At all other frequencies, the resonant circuit offers negligible impedance, and the desired signals pass easily.

The parallel trap is a tuned circuit which is placed across, or in shunt with, the circuit. Figure 7-6(B) shows a series-resonant circuit used in this manner. At the frequency for which it is set, the trap acts as a short circuit, bypassing the resonant frequency to ground and preventing further penetration into the circuit. At other frequencies, the trap circuit presents a relatively high impedance, permitting these signals to proceed to the following stage. It is important that the parallel trap have a very high Q so the circuit will bypass only a narrow range of frequencies.

The absorption trap, shown in figure 7-6 (C), is a widely used type of rejection circuit. It consists of a coil and a fixed capacitor inductively coupled to the load inductor of an IF amplifier. When the IF amplifier receives a signal at the resonant frequency of the trap circuit, a high circulating current develops in the trap network as a result of the coupling between the trap and the load inductor. The voltage in the load coil, L1, becomes quite low at the trap frequency. Consequently, very little of this interference voltage is permitted to reach the following stage. It is convenient to think of this kind of trap as being able to absorb all of the energy of the frequency to which it is tuned, and therefore no energy at that frequency is left available to pass on into the next stage.

Degenerative traps, as illustrated in figure 7-6 (D and E), are designed to reduce the gain of an amplifier for frequencies to which the trap is tuned. These traps are used in the emitter circuit of a solid-state amplifier, or in the cathode leg of a vacuum-tube circuit. In the latter application, the traps are often called "cathode traps." The two types of traps normally used to provide the degeneration are the absorption type and the series type. Figure 7-6(D) shows an absorption type in which L_1 in series with C_1 forms a broadly tuned series-resonant circuit at the frequency to which the amplifier is tuned. This permits the amplifier to function normally for all signals within its frequency range. At the resonant frequency of the trap, however, a high impedance is reflected into the emitter or cathode circuit by the trap, and the gain of the stage is reduced by degeneration.

The series type of degenerative trap, illustrated in figure 7-6(E), places a parallel circuit directly into the emitter or cathode leg. At the resonant frequency of the trap, the impedance in this part of the amplifier circuit will be high, producing a large degenerative voltage and thus reducing the gain of the amplifier. At all other frequencies, the impedance of this parallel network is low. Only a small degenerative voltage appears, and therefore only a slight loss in gain occurs except at the undesired frequency.

A trap that is more complex than any of the foregoing circuits, but also more effective, is the bridged-T trap shown in figure 7-6(F). In this circuit, L_1, C_1, and C_2 are resonated at the frequency of the signal to be rejected. Now, if the resistance of R is properly chosen, the attenuation imposed upon a signal to which L_1, C_1, and C_2 are resonated will be great. Ratios of 50 and 60 to 1 are easily attainable using standard components. This means the strength of the desired signal at the output of the trap will be 50 to 60 times greater than the strength of the undesired signal.

CIRCUITS

Figure 7-7 is a schematic diagram of a typical video IF system found in many color TV sets. This system has three NPN transistor stages that are impedance coupled and pass a band of frequencies centered at 43.8 MHz. Input to the IF system is through a plug-in link from the mixer stage in the tuner. The mixer output coil is tuned to position 42.17 MHz at the 50 percent point on the IF response curve, and the impedance of the coil is tapped to match the impedance of the coax link. Q_1, the first IF amplifier, is coupled to the input coax link through LA_2 and CA_1. LA_2 is tuned to position 45.75 MHz at the 50 percent point on the opposite side of the response curve from the 42.17 MHz point. Both 50 percent points on the

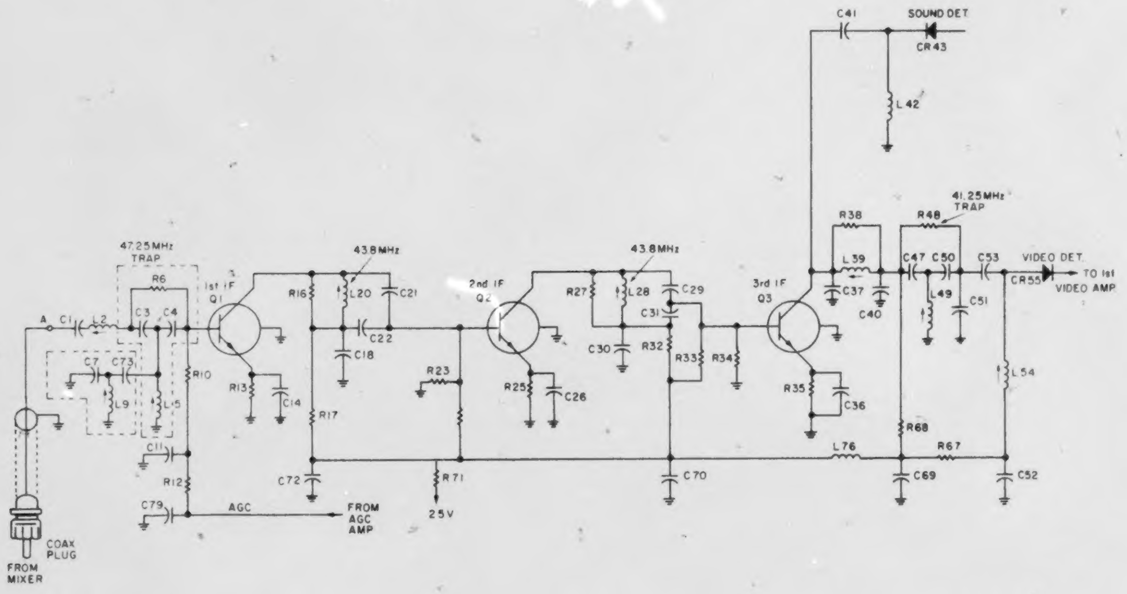

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Figure 7-7.—Solid-State color IF amplifier.

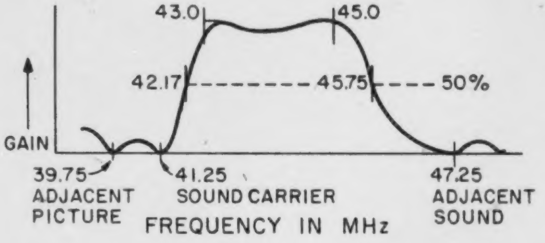

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Figure 7-8.—Video IF response curve for a color set.

IF response curve are shown in figure 7-8. The mutual coupling of LA_2 and the mixer output coil provide a wide bandpass through the coax link.

There are two sound traps at the input to Q_1—one tuned to reject the adjacent channel sound frequency at 47.25 MHz and the other tuned to suppress the 41.25 MHz associated sound carrier. The 47.25 MHz trap consists of RA_6, CA_3, CA_4, and LA_5. This trap is a bridged-T configuration and delivers, to the base of Q_1, two 47.25 MHz voltages that are equal but 180 degrees out of phase. One of these voltages is developed across RA_6 while the other is developed across CA_3, CA_4, and LA_5. At the base of Q_1 the voltages cancel each other, thus eliminating the adjacent channel sound carrier from the IF band. The 41.25 MHz trap is a series-resonant network consisting of CA_7, CA_{73}, and LA_9. This trap, loosely coupled to the input circuit, improves selectivity and provides better fine tuning.

In this system, AGC is applied only to the first IF amplifier stage. As the AGC voltage increases, forward bias is developed at the base of Q_1. This bias increases the current flow through the transistor and, consequently, causes a greater voltage drop across RA_{16}, thus reducing the stage gain.

In the collector circuit of Q_1, CA_{21} and CA_{22} divide the voltage developed across LA_{20} and couple it to the base of Q_2. The junction of the two capacitors matches the impedance of the coil to the base of Q_2. LA_{20} is tuned to 43.8 MHz, which is the center of the IF system passband. Coupling between Q_2 and Q_3 is identical to that between Q_1 and Q_2, with LA_{28} also tuned to 43.8 MHz. The associated sound carrier is tapped off at the collector of Q_3, the third IF amplifier.

The output circuit of the IF system is, in effect, very similar to the input circuit. Here, LA_{39} is tuned to position 42.17 MHz at the 50 percent point on the IF response curve, as was indicated in figure 7-8, and LA_{54} positions 45.75 MHz at the same point but on the opposite slope. A bridged-T trap, consisting of RA_{48}, CA_{47}, CA_{50}, and LA_{49}, rejects the 41.25 MHz associated sound carrier, thus preventing it from reaching the video detector. The three sound traps in this system, two at 41.25 MHz and one at 47.25 MHz, in addition to suppressing interference, account for most of the selectivity in the IF system.

VIDEO DETECTORS

The video detector in a television receiver performs essentially the same function as the second detector in a superheterodyne amplitude-modulated radio receiver. It rectifies the signal (video and sync pulses) fed to it by the video IF system, removes the IF components, and feeds the remaining signal and sync information to the video amplifier. Various circuit arrangements, employing either diodes, electron tubes, or crystals, are used by the manufacturers of television receivers.

One type of diode detector is shown in figure 7-9. Two methods of connecting the diodes are shown. The output of CR1 has a negative picture phase, and CR2 has a positive picture phase.

In figure 7-9(A), the low amplitude positive going picture signals correspond to the brighter portions of the picture, and higher amplitudes correspond to progressively darker portions of the picture. This corresponds to the negative picture phase.

The low amplitude negative-going picture signals of CR2 correspond to the brighter portions of the picture, and higher amplitudes correspond to progressively darker portions of the picture. This corresponds to the positive picture phase (7-9(B)).

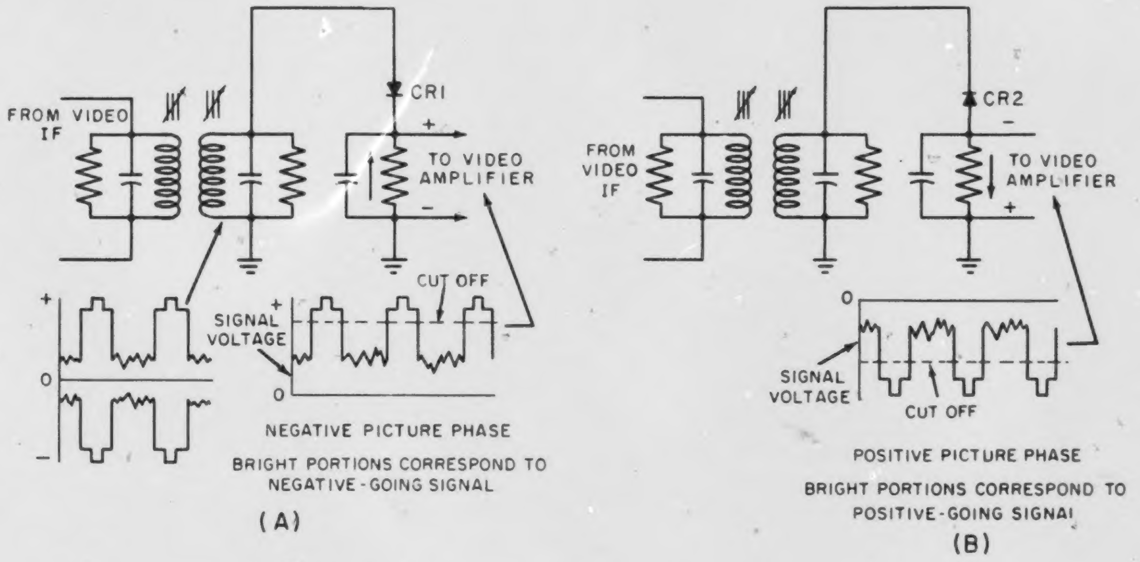

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Figure 7-9.–Video diode detectors.

The concept of negative picture phase may be made clearer from the following considerations. A video signal having a negative picture phase causes the cathode of the picture tube to be driven in a positive direction beyond cutoff during the blanking pulses. During the darker portions of the picture, the cathode is biased in the positive direction, but not to cutoff. Consequently, few electrons reach the picture tube screen, and the screen is relatively dark. During the brighter portions of the picture the cathode is driven only slightly in the positive direction, and many electrons reach the picture tube screen. The screen is therefore relatively bright.

The concept of positive picture phase may be made clearer from the following considerations. A video signal having a positive picture phase causes the grid of the picture tube to be driven negative below cutoff during the blanking pulses. During the darker portions of the picture the grid is driven considerably negative, but not to cutoff. Consequently, fewer electrons reach the picture tube screen, and the screen is relatively dark. During the brighter portions of the picture, the grid is driven only slightly negative, and many electrons reach the picture tube screen. The screen is therefore relatively bright.

In the United States, negative transmission is used; the television signal is transmitted with the negative picture phase. In certain other countries, positive picture transmission is used.

The output of the detector in the receiver may have a positive or a negative picture phase as indicated in figure 7-9, irrespective of the type of transmission used. In either case, the video amplifiers must supply a signal having a positive picture phase to the grid of the picture tube. If the signal is applied to the cathode of the picture tube, it must have a negative phase.

As a review of the signal processing, refer to figure 7-1 during the following discussion. Up to this point the television signal has been received and amplified by an RF stage, converted to another frequency (IF) by means of a mixer, further amplified by the IF stages, and rectified by the diode detector. The strength of the signal at the output of the detector is not sufficient to drive the picture tube, and therefore one or more stages of video amplification are necessary.

VIDEO AMPLIFIERS

After the video signal (containing the video information and the blanking and sync pulses) has been rectified in the second detector, it must be amplified in one or more video amplifiers before it is applied to the picture tube. Because a wide band of frequencies must be passed without discrimination by the video amplifiers, they must be carefully designed. Special high and low frequency compensating circuits must be used to extend the approximate range of frequencies passed from 30 hertz to 4 MHz. In other words, frequency distortion must be eliminated as much as possible.

The low frequency video components include the low frequency ac variations (represented on the picture screen as portions of the image that do not contain fine detail), the blanking pulses, and the sync pulses (vertical and horizontal). The high frequency video components are the high frequency ac variations that produce the fine detail on the picture screen. In addition to the low frequency and the high frequency components in the transmitted signal, there is a zero frequency, or dc, component present.

If all of the frequency components are not properly amplified in the video amplifier section, a distorted image is produced. The distortion may appear as a lack of fine detail, a lack of image sharpness in the larger objects, or a lack of contrast.

In addition to frequency distortion, phase distortion must also be eliminated as much as possible. In effect, phase distortion means that certain components (frequencies) that make up complex waveforms are not passed by the amplifier in the same length of time that other frequencies are passed. For example, in resistance-coupled amplifiers the coupling capacitor and the grid resistor, acting together, cause a phase shift that varies with the frequency.

Phase distortion may alter the background of the picture shown on the television screen; portions that should be white may be gray or even black. At the lower frequencies, excessive phase shift may cause larger objects to be blurred on the screen. At the higher frequencies, excessive phase shift causes the fine detail to be blurred.

The average resistance-coupled amplifier has a flat response of only a few thousand hertz and is therefore not suitable for amplifying video frequencies. In order to amplify the higher frequencies as much as the middle range of frequencies, it is necessary to use some form of high frequency compensation. This type of compensation commonly takes the form of shunt compensation or series compensation or a combination of both. An example of the combination type of compensation is shown in figure 7-10.

In a resistance-coupled amplifier, the output capacitance of the first amplifier stage, the distributed capacitance of the wiring, and the input capacitance of the second amplifier stage tend to shunt the high frequencies of the first stage to ground, thereby leaving less output voltage at these frequencies available to the second stage. The high frequencies are therefore not amplified as much as the middle range of frequencies.

This shunting effect is compensated for (or the frequency range extended) by the use of a small inductor (fig. 7-10(L1)) inserted in series with the load. The value of this inductor is so chosen that it will neutralize the distributed (output and input) capacitance of the circuit. That is, this inductor together with the

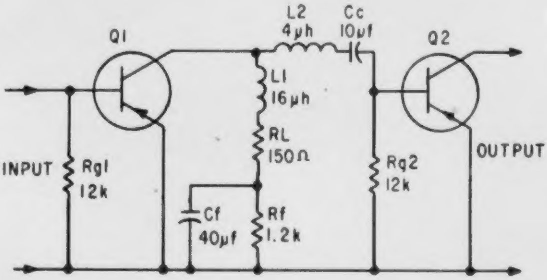

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Figure 7-10.—Transistor video amplifier.

distributed capacitance, forms a parallel-resonant circuit that is resonant at a frequency where the response curve begins to fall appreciably. The frequency range is thereby extended. This type of compensation is called shunt compensation, and the coils are called peaking coils.

Series compensation is also used. In this case, a small inductor (fig. 7-10(L2)) is added in series with the coupling capacitor and forms a series-resonant circuit (resonant at a frequency where the response curve begins to drop) with the distributed capacitances. At resonance, increased current flows through these capacitances, and larger voltages are available at the input of Q2. To prevent a sharp peak in the response curve, a resistor is shunted across the series inductor.

In order to amplify the lower frequencies as much as the middle or high range of frequencies, it is necessary to use some form of low frequency compensation. At low frequencies, the reactance of the coupling capacitor is large and much of the signal voltage is dropped there and not available at the base input. A large coupling capacitor could be used; if this were done, the stray capacitance and leakage current would be increased. Of course, a coupling capacitor introduces some phase shift at low frequencies.

Both the loss in gain and the increase in phase shift at the lower frequencies may be compensated for in part by dividing the load resistor into two parts (fig. 7-10, RL and Rf) and bypassing one part with a capacitor (Cf). At the lower frequencies, the load includes both resistors, and therefore the output voltage is higher. At the higher frequencies, a portion of the load is effectively bypassed by the capacitor, and the output is proportionately lower.

DC RESTORERS

The dc restorer (or clamper) restores the dc component of a pulse waveform after this component has been removed by the passage of the waveform through the coupling capacitor in the video amplifier stage. It is necessary to reinsert the correct dc component at the input of the television picture tube if the correct level of background illumination is to be maintained. Also, if the correct dc component is not reinserted, the blanking level will vary (instead of remaining constant, as it should), and retrace lines will appear on the screen during the time the blanking voltage is insufficient to cut off the picture tube during retrace.

The average brightness of one scanned line may differ widely from the average brightness of another scanned line, as indicated in figure 7-11 (A).

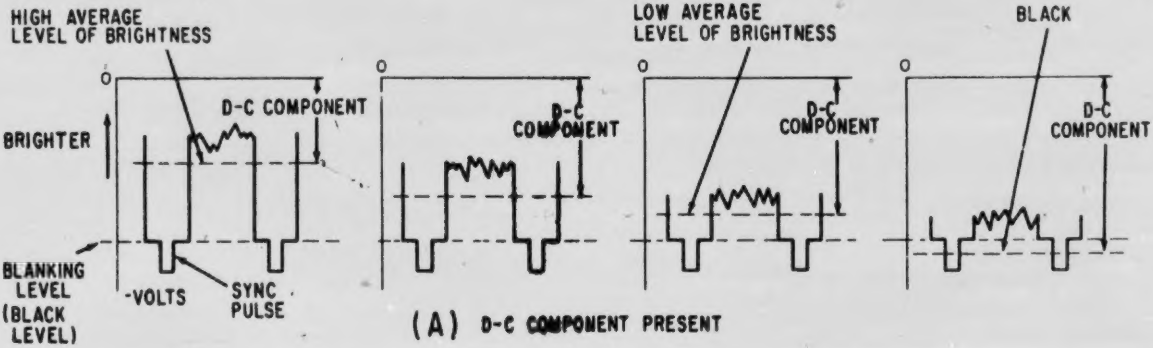
The average dc component depends on the average brightness of a scanned line. A low dc component in the negative direction means a high level of brightness exists during that line; a high dc component in the negative direction means a low level of brightness exists during that line. The average dc component therefore establishes the blanking level.

Figure 7-11 (B) illustrates what happens when the dc component is removed by the passage of the video signal through a coupling capacitor. Although the picture tube may be biased so that it is not driven in a positive direction beyond a certain value, nevertheless the blanking level varies and the retrace is often visible. The background brightness level also differs from that at the transmitter.

A simplified dc restorer circuit is shown in figure 7-12. The function of the circuit is to restore the dc component that was lost when the video signal passed through the coupling capacitor of the video amplifier. DC restoration is accomplished by adding to the instantaneous ac signal enough dc voltage to bring the blanking voltage to the cutoff point.

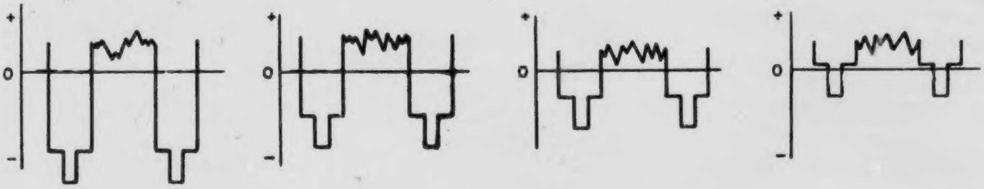
The action of the dc diode restorer may be explained in the following manner: Without the diode, the input signal voltage has the appearance of that shown in figure 7-11 (B). During the negative portion of the cycle (when the blanking and synchronizing pulses are active), the diode (fig. 7-12) conducts because its cathode is negative and its plate is positive. Capacitor C charges rapidly through the diode and has the polarity indicated. The amount of the charge (voltage across C) depends on the strength of the input signal.

During the positive portion of the signal, shown above the 0 line in figure 7-11 (B), the


HIGH AVERAGE LEVEL OF BRIGHTNESS
LOW AVERAGE LEVEL OF BRIGHTNESS
BLACK
0
D-C COMPONENT
BRIGHTER
BLANKING LEVEL (BLACK LEVEL)
-VOLTS
SYNC PULSE

(A) D-C COMPONENT PRESENT

WHEN THE VIDEO SIGNAL PASSES THROUGH A COUPLING CAPACITOR, THE D-C COMPONENT IS REMOVED, LEAVING AN A-C SIGNAL THAT VARIES ABOUT THE ZERO LINE AS SHOWN BELOW.



(B) D-C COMPONENT REMOVED

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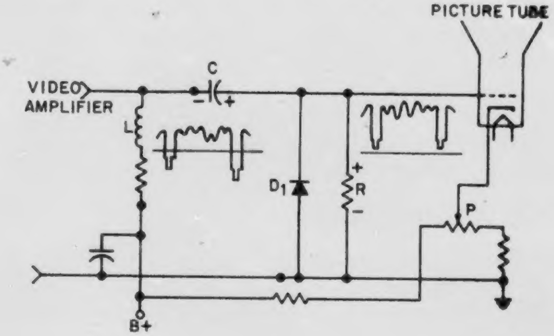
Figure 7-11.—Function of the dc component in the video signal.



244.200

Figure 7-12.—Diode dc restorer.

diode cannot conduct, and C (fig. 7-12) discharges slowly through R. A positive potential, which reduces the bias on the picture tube, is thus applied between grid and cathode during the scan interval between the blanking pulses. During this interval, the diode is effectively an open circuit, and the video signal appears across R in series with the dc voltage supplied by C. The greater the input voltage, the less the net bias remaining on the grid of the picture tube and the higher the average brightness. Thus, the condition existing in figure 7-11 (A) is reestablished.

When direct coupling is employed between all stages in the video amplifier section, including the coupling stage between the video detector and the first video amplifier and picture tube, dc restoration is not required. An example of this direct coupling is shown in figure 7-13. Detector D1 is direct coupled to first video amplifier Q1 through peaking coil L12. This is an emitter-follower stage which develops a signal across R48. The base of second video amplifier Q2 receives its signal directly from the emitter of Q1. The second amplifier is a conventional (common emitter) amplifier stage direct coupled to the picture tube through the contrast control, diode D2, and peaking coil L18. Diode D2 is used to compensate for nonlinearity in transistor amplifier Q2 on high-amplitude signals.

TELEVISION SOUND SYSTEMS

The sound system of a television receiver is essentially the same as that of an FM receiver. FM receivers are described in *Basic Electronics*; it is unnecessary to describe them in detail in this chapter. An important difference, however, is the system used for IF amplification. There are two systems in use–the split-sound system and the intercarrier-sound system.

SPLIT-SOUND SYSTEM

A simplified version of a split-sound system is shown in figure 7-14. Although a large number of the newer television receivers use intercarrier sound, some sets still employ the split-sound system. In the split-sound system, the sound IF is removed at the output of the converter (or from the first video IF) and amplified in a series of sound IF amplifiers.

INTERCARRIER-SOUND SYSTEM

A simplified version of an intercarrier system is shown in figure 7-15. This system is now used in most commercial sets. Its obvious advantage is that the sound is amplified along with the video, which means fewer audio stages are necessary.

The carrier IF in the output of the RF unit is the same as those in the output of the RF unit

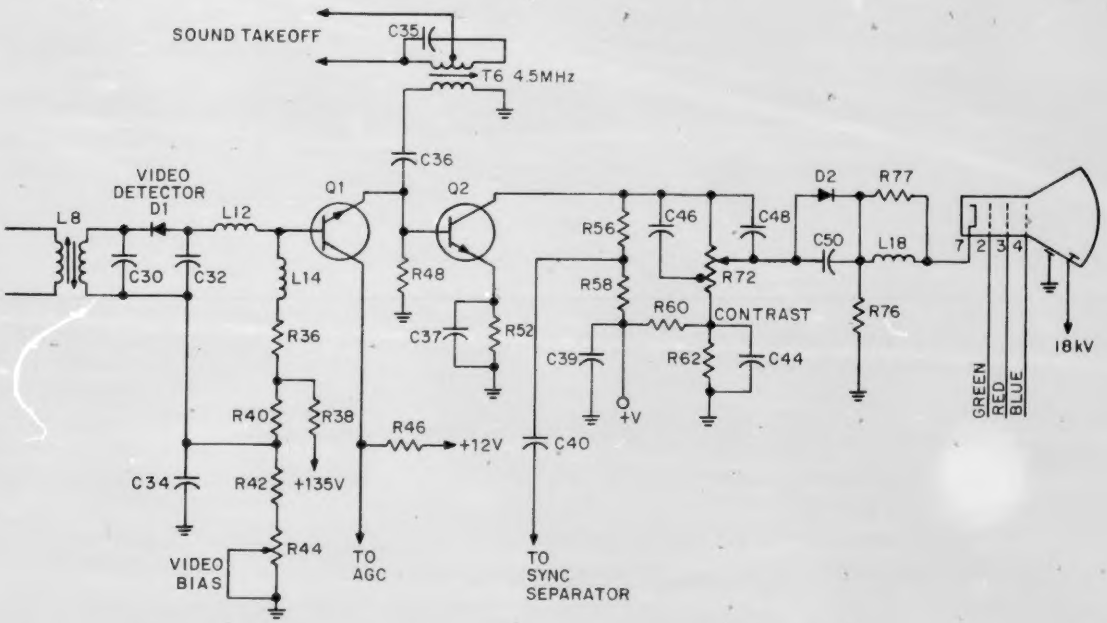


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Figure 7-13.—Direct-coupled video amplifier stages.

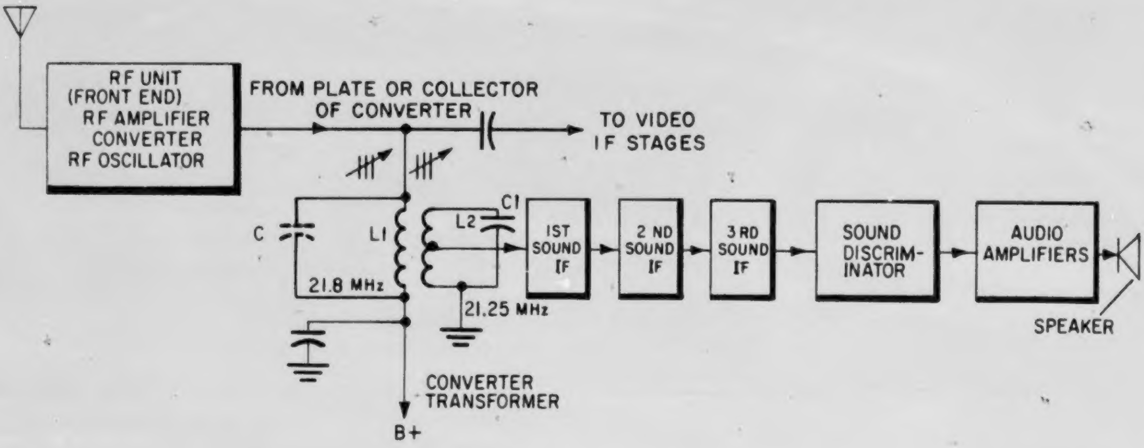

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Figure 7-14.—Split-carrier sound system.

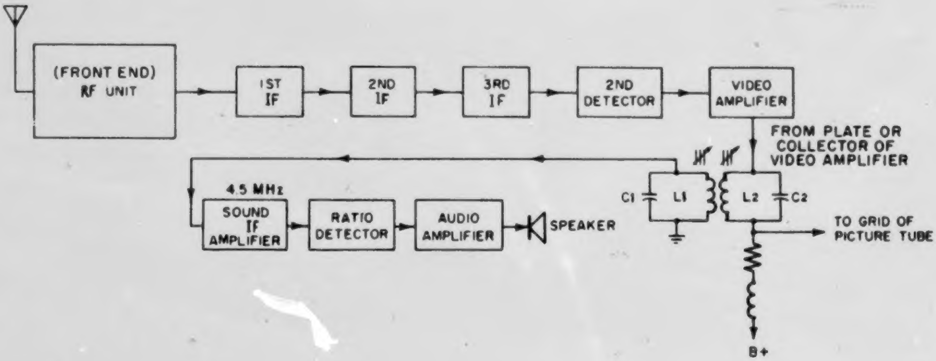

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Figure 7-15.—Intercarrier sound system.

in the split-sound system. Because the IF stages in the intercarrier system must pass both the picture and the sound IF carrier, the bandpass must be wide enough to pass both of these frequencies.

Although both video and sound IF carrier frequencies (with their sidebands) are amplified in the IF stages, the sound IF is not amplified as much as the picture IF. By keeping the sound IF level much lower than the picture IF level, a 4.5 MHz beat note, containing only the modulation of the original RF sound carrier, is obtained at the second detector. This beat note is the difference in frequency between the sound carrier IF and the picture IF and, in fact, is the sound IF signal after it has passed the second detector. The difference between the video and sound carrier frequencies forms the basis of the sound IF and is always 4.5 MHz.

The 4.5 MHz sound is extracted, as shown in figure 7-15, from the video amplifier by a 4.5 MHz trap. The sound IF then passes through a

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sound IF amplifier, which also serves as a limiter. The signal is then passed to a ratio detector and an audio amplifier and speaker.

Integrated-circuit (IC) Sound System

An ideal IC for a TV sound section would have 5 terminals: one for ground, one for power, a 4.5 MHz input, a lead for the volume control, and a connection which goes directly to the speaker. Figure 7-16 shows a TV-FM sound circuit which contains an IC and 13 other components. The two coils are single-slug tuned and simple to align.

The power transistor and output transformer are required because ICs are usually small devices with low-power dissipation. Some additional gain is therefore required to change to the power and impedance requirements of a 4-ohm, 2-watt speaker.

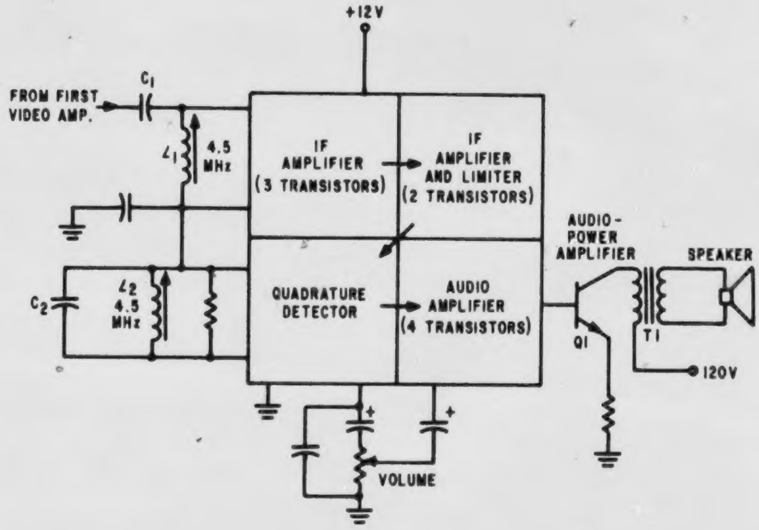
The two IF amplifiers are not transformer coupled or resonant-circuit coupled. Instead, adequate selectivity is obtained with just the resonance of L_1 and C_1. A gain of 2,000 at 4.5 MHz is typical. This large gain saturates the last IF amplifier and produces the square-wave signal required for the quadrature detector.

The quadrature detector is an FM detector circuit that acts as both a discriminator and a limiter in one stage. This type of FM detector is easily produced as part of an integrated circuit. Tuning merely requires making L_2 and C_2 resonant at 4.5 MHz.

The audio-voltage amplifier is a 3 stage, 4 transistor, dc coupled amplifier. Direct coupling allows a good bass response and also avoids the use of capacitors. Note that, except for the speaker transformer and the two capacitors associated with the volume control, this system would have a bass response down to dc.

PICTURE TUBES

A monochrome picture tube is a specialized form of the cathode-ray tubes you studied in *Basic Electronics*, NAVPERS 10087 (Series). An electron gun in the tube directs a beam of electrons toward a fluorescent material on the screen, which glows when struck by the electrons. Between the gun and the screen are deflection coils which deflect the beam



244.202

Figure 7-16.—IC sound system.

horizontally and vertically to form a raster. The brightness of the screen at any point depends upon the number and velocity of electrons striking that point. The brightness of the picture is controlled by varying the grid-bias voltage with respect to the cathode voltage. This bias can be changed by varying either the cathode voltage or the grid voltage.

Color picture tubes operate on the same basic principle, except that the screen is coated with different types of phosphors which produce colors when struck by electron beams. As you saw in the previous chapter, there are three basic or primary colors used in combination to produce all the other desired colors. These primary colors are red, green, and blue. In a three gun color picture tube, figure 7-17, there is a separate gun for each of the color phosphors. The tube's screen consists of small, closely spaced phosphor dots of red, green, and blue. The dots are arranged so a red, green, and blue dot form a small triangle. The shadow mask provides a centering hole in the middle of the triangle of dots. The convergence electrode causes the three separate electron beams to meet and cross at the hole in the shadow mask.

Each electron gun is electrostatically focused by a common grid voltage. In other words, each gun has its own electrode but all three are connected together requiring only one grid voltage. The three electron beams scan the screen as controlled by the deflection yoke which is mounted externally around the neck of the tube. As the three beams scan the phosphor screen horizontally and vertically in the standard scanning pattern, the dot triads are caused to light according to the video input signals.

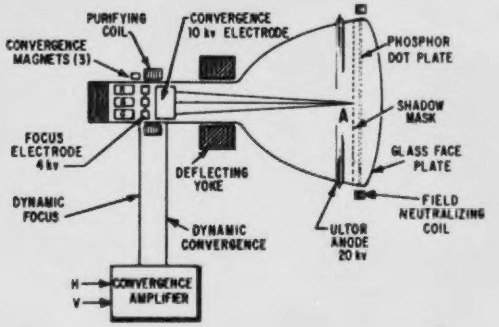


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Figure 7-17.—Color picture tube.

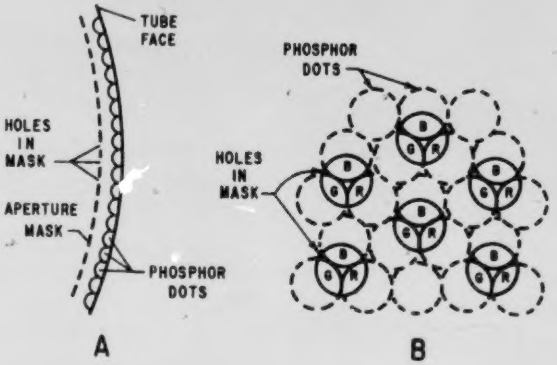

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Figure 7-18.—Color picture tube (A) side view, (B) front view.

The purifying coil produces a magnetic field within the tube which aligns the electron beams parallel to the neck of the tube. Rotating the purifying coil adjusts the electron beams so they strike their respective color dots without striking its neighboring dots. When this adjustment is made for the red dots, the other two electron beams are aligned as well.

The high voltage anode is a metallic ring around the tube. The field neutralizing coil aids color purity at the outer edges of the picture tube. A metal shield, called a mu-metal shield, is placed around the bell of the tube to prevent stray magnetic fields from affecting the electron beams.

CODING

Type numbers for picture tubes are coded to indicate the approximate size of the tube and the type of phosphor used on its screen. For example, a tube coded 21DAP4 has a rectangular face with a diagonal measurement of approximately 21 inches. The P4 portion of the designation indicates the type of phosphor. The letter or letters (DA in this example) between tube size and type of phosphor indicate some type of modification to the basic tube. For example, the DA could mean this tube has an aluminized screen whereas the basic tube did not.

COLOR CIRCUITS

A color television receiver, as shown in figure 7-19, contains many circuits which are markedly different from the circuits used in monochrome (black-and-white) receivers. The differences are outlined in the following paragraphs.

The tuner and amplifier stages in color receivers are designed to pass a wider band of frequencies than do conventional monochrome receivers. Wideband characteristics in these stages are necessary to assure uniform amplification of the high-frequency color subcarrier sidebands that carry the chrominance (color) information.

The video amplifier stage, which in monochrome receivers usually consists of only one stage of amplification, contains two and usually three stages of amplification. Additional stages of amplification are made necessary because the luminance signal in color receivers is used to drive the cathodes of all three electron guns in the CRT, as compared to the single-gun monochrome CRT.

A video delay line, usually located between the video output stage and the CRT, is used to delay the luminance signal for a fixed period of time so the luminance and chrominance information arrive at the CRT simultaneously. As shown in the block diagram of figure 7-19, this fixed delay is necessary because the chrominance signals pass through additional stages before being applied to the control grids of the CRT. Were it not for the delay of luminance information, the two signals would not arrive in coincidence and a distorted video presentation would result.

Due to the use of an aperture mask type of picture tube, the brightness of a color receiver is characteristically low; higher voltage is necessary to maintain adequate brightness. The output voltage of the high voltage supply is nominally 20-25 kv as compared with 15-18 kv for monochrome receivers. All three electron guns must be sharply focused onto the screen to obtain good monochrome and color reproduction. The focus rectifier in color receivers provides a variable focus voltage (4 to 5 kv) that is applied to the electrostatic focus elements of the CRT. Another factor that requires design techniques much different from those used in monochrome receivers is that the load of the high-voltage rectifier must be held fairly constant. Otherwise, severe blooming or shrinking of picture size will occur during reception of signals having a varying brightness level. The voltage regulator circuit provides a fairly constant anode voltage regardless of the brightness level of incoming signals.

The color demodulator section is the "heart" of the color television receiver. In this section, the 3.58 MHz subcarrier sidebands are demodulated to produce color information signals. The color information signals are then applied to a matrix where color difference signals are produced by matrixing proportionate amounts of the demodulated signals. The color difference signals are in turn amplified and applied to the control grids of the CRT in the proper proportions to reproduce the televised scene.

The color convergence circuits provide a secondary control over the electron beam of each gun. Convergence of the three electron beams to exact locations on the face of the CRT is necessary to produce good monochrome and color images on the three-gun CRT.

Other differences in color receiver circuits, such as automatic color control, tuning indicators, and color reception indicators, serve to simplify the operation of front-panel controls.

BANDPASS AMPLIFIER

The chrominance 3.58 MHz subcarrier signal and the color-synchronizing burst signal are coupled from the first video amplifier to a bandpass amplifier (fig. 7-19). The bandpass amplifier is tuned to amplify the subcarrier frequency and reject the lower-frequency video signals. The 3.58 MHz subcarrier sideband signal,

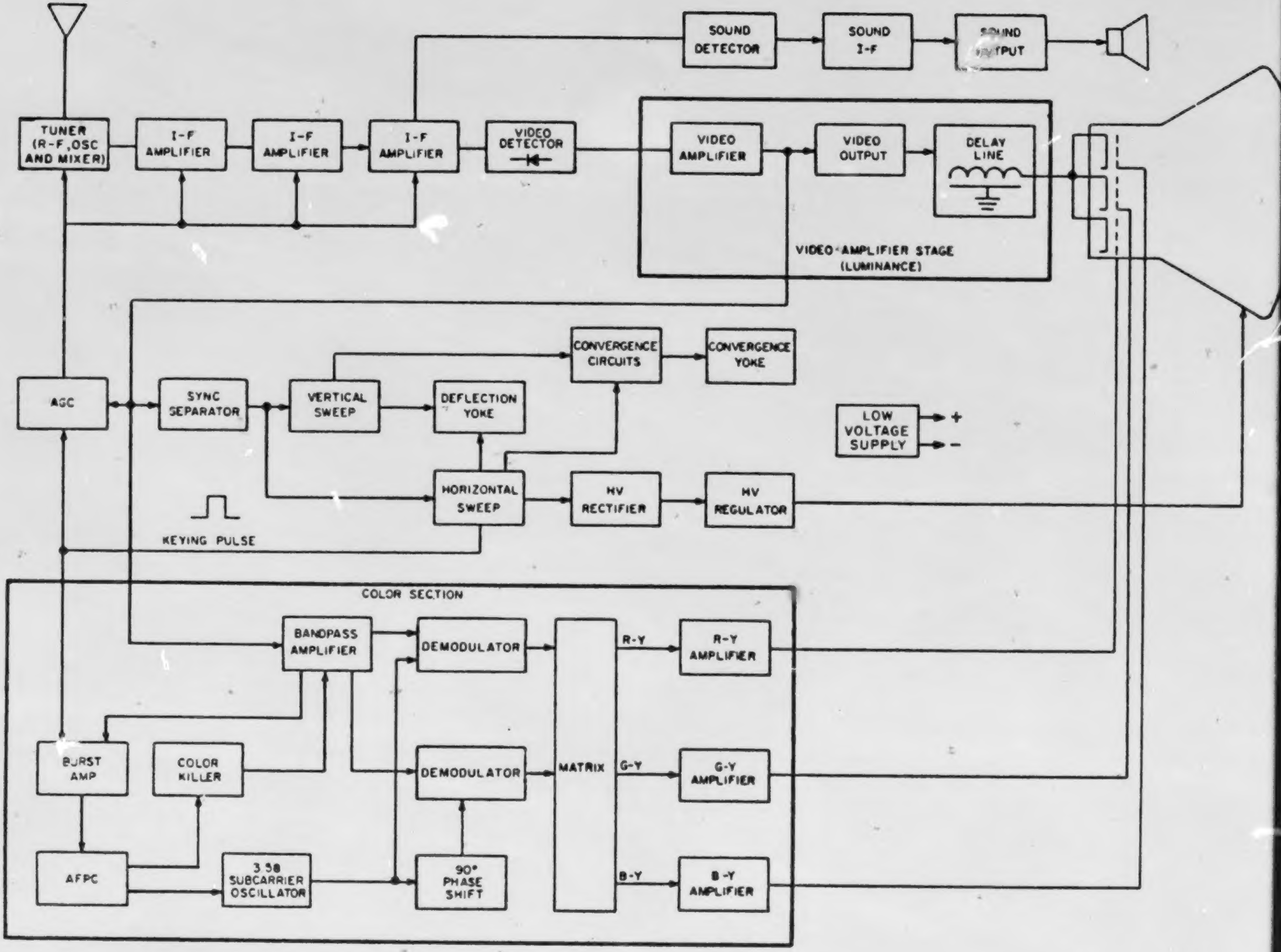

Figure 7-19.—Color television receiver, block diagram.

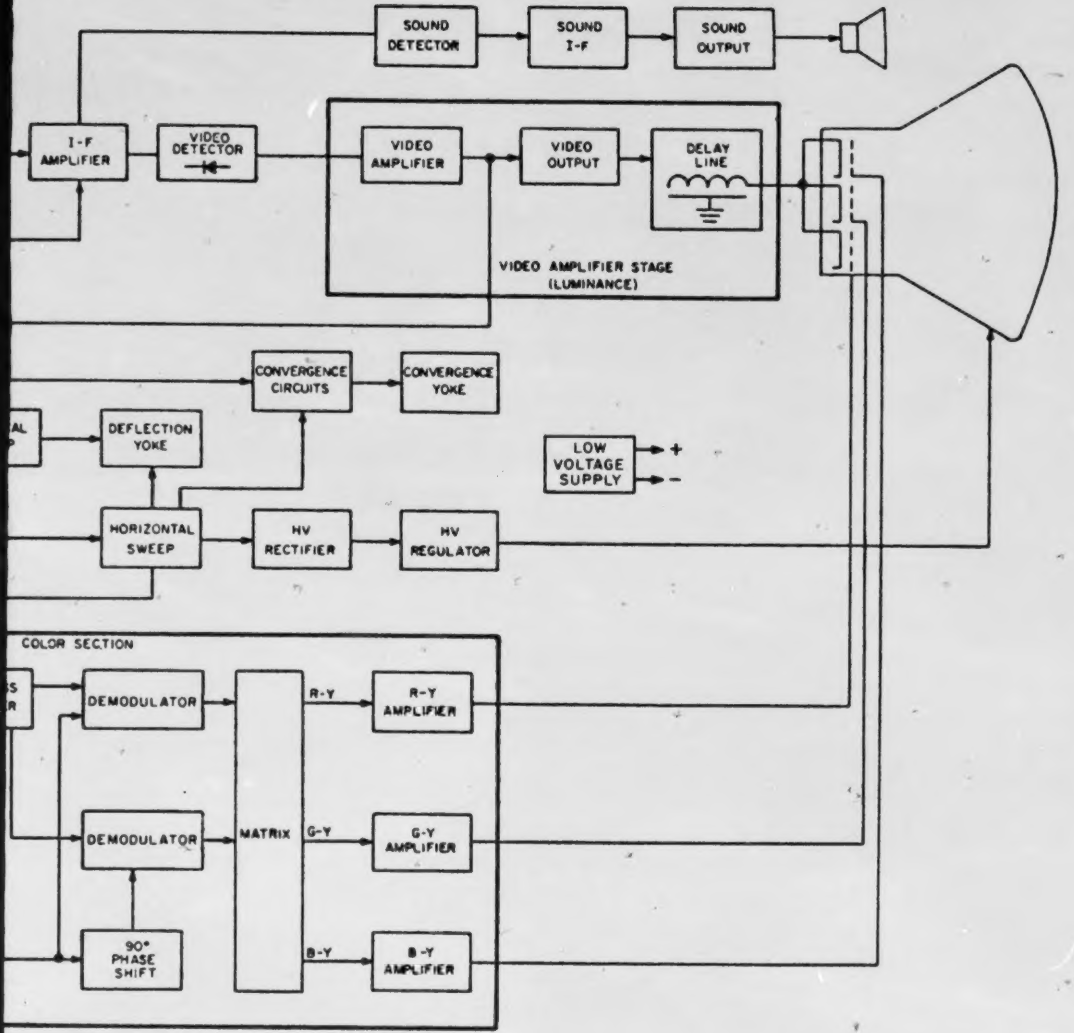

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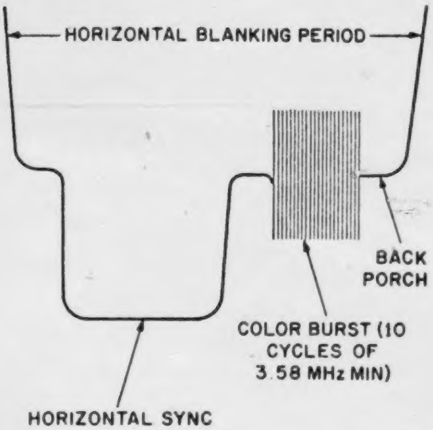
Figure 7-19.—Color television receiver, block diagram.

which results from the addition of the I and Q chrominance signals to a 3.58 MHz oscillator signal, must now be demodulated to recover the color information. Consequently, a locally generated 3.58 MHz oscillator signal must be mixed with the subcarrier sideband to produce the chrominance signals. The frequency and phase of the locally generated signal, however, is critical and must be nearly identical to that of the station transmitter in order to recover exact color information. Therefore, the local oscillator is constantly synchronized by the burst reference signal. At the output of the bandpass amplifier, the burst signal, which is composed of approximately 10 cycles of the 3.58 MHz signal generated by the transmitting station's oscillator (fig. 7-20), is selected by a burst separator. The burst separator in this instance is a time-gated amplifier that is gated, or "keyed" on, by a horizontal pulse from the flyback transformer during the horizontal retrace time. (Remember that the burst signal is transmitted on the "back porch" of the horizontal synchronizing pulse; consequently, when the horizontal pulse becomes negative, a positive flyback pulse is available for turning on the burst gate to allow the 10 cycles of burst to pass through and be amplified.) The burst signal is then applied to the automatic frequency and phase control (AFPC) circuits which control the 3.58 MHz local oscillator.


HORIZONTAL BLANKING PERIOD
BACK PORCH
COLOR BURST (10 CYCLES OF 3.58 MHz MIN)
HORIZONTAL SYNC

40.244

Figure 7-20.—Location of color burst on horizontal sync pulse.

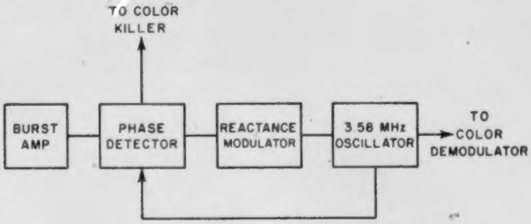


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Figure 7-21.—AFPC Circuit.

AUTOMATIC FREQUENCY AND PHASE CONTROL (AFPC) CIRCUIT

The burst signal is coupled to the AFPC circuit, as shown in figure 7-19. The reference circuit is usually one of two types: the stable oscillator-phase detection type or the frequency-phase detection supplemented type; only the former will be discussed. The stable oscillator-phase detection type of AFPC, shown in figure 7-21, accepts the keyed signal from the burst gate and applies it to a phase detector. In the phase detector, the locally generated oscillator signal is compared with the incoming burst signal and an error or corrective voltage is developed. The error voltage is applied to a reactance modulator which is parallel connected across the 3.58 MHz oscillator tank. The reactance modulator acts as a variable capacitor, its capacitance either increasing or decreasing, depending upon the polarity of the voltage applied. Thus, when the phase of the local oscillator changes appreciably, the voltage developed by the phase detector changes the capacitance of the reactance modulator, and the oscillator output signal shifts in phase in order to correspond to the burst signal.

The frequency of the local oscillator is primarily controlled by an input crystal tank circuit; however, when the local oscillator does drift off frequency, the phase detector error or correction voltage causes the oscillator to swing through its frequency range until the phase and frequency error voltages equal zero and the oscillator locks in.

COLOR KILLER CIRCUIT

The purpose of the color killer circuit is to disable the color circuits when a monochrome signal is being received. Usually this is accomplished by biasing the bandpass amplifier below cutoff. No signal passes until the burst is applied to the color killer circuit. In order to demonstrate the effectiveness of a color killer circuit, assume a signal of high noise characteristics present at the input of the bandpass amplifier. The tube goes into conduction, which enables the color circuits and results in a colored noise presentation on the CRT. The color killer circuit prevents this noise presentation on the CRT by sensing the absence of the color burst signal. If the burst is absent, the killer circuit conducts and applies bias to the bandpass amplifier, thereby cutting off the color circuits. When the color killer circuit senses the presence of the burst signal, such as by sensing a negative voltage at the output of the phase detector shown in figure 7-21, the killer circuit ceases to conduct, and thereby permits the bandpass amplifier to admit the chrominance information.

In later model receivers, various circuits have been devised to eliminate this undesirable "color" during monochrome transmission. One simple method involves merely biasing off the bandpass amplifier by adjusting the familiar "color control" on the front of the receiver. However, a second and more sophisticated method of color killer circuit operation, which has been adopted by many manufactures, is the circuit shown in figure 7-22. This diode phase detector circuit uses the 3.58 MHz burst signal and the 3.58 MHz signal from the crystal oscillator as inputs. It compares the phase of these two signals and generates a dc output proportional to their phase difference.

Note the location of the color killer potentiometer (R1). It is adjusted so the Q1 is biased up to a point just slightly below cutoff. If the bursts are not present in the video signal, then a large phase error is detected. This causes a positive bias to add to the bias mentioned above and Q1 turns on. This sends a negative bias to the chroma amplifiers, turning them completely off. If color bursts are present, the color killer detector does not turn Q1 on, thereby allowing the chroma amplifiers to operate normally.

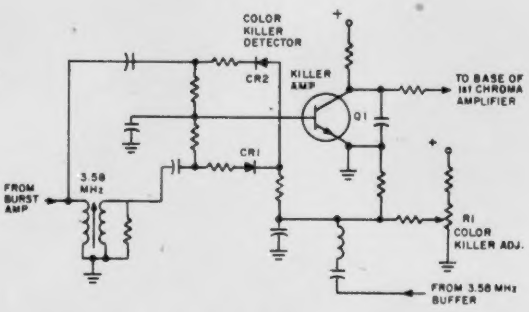

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Figure 7-22.—Color killer.

CHROMA DETECTORS

The purpose of the chroma detector circuit (fig. 7-23) is to recover the chrominance components from the 3.58 MHz subcarrier sideband, which are transmitted by the station transmitter. The chrominance components are then used by the receiver circuits to reproduce a replica of the televised scene of the face of the CRT.

The synchronous detector is a phase-sensitive device that detects the phase difference between a 3.58 MHz reference oscillator signal known phase, and the incoming 3.58 MHz modulated sideband signal. When both signals are inphase, a negative output is obtained, and when the signals are out-of-phase a positive output is obtained. Since the I and Q components of the video signal are always in quadrature (90 degrees out-of-phase), a synchronous detector may be used to separate the color video signals from the modulated sideband signal. If the phase difference between the two signals is 90 degrees, the output is always zero.

The maximum output occurs at zero, and 180 degrees phase difference between the input

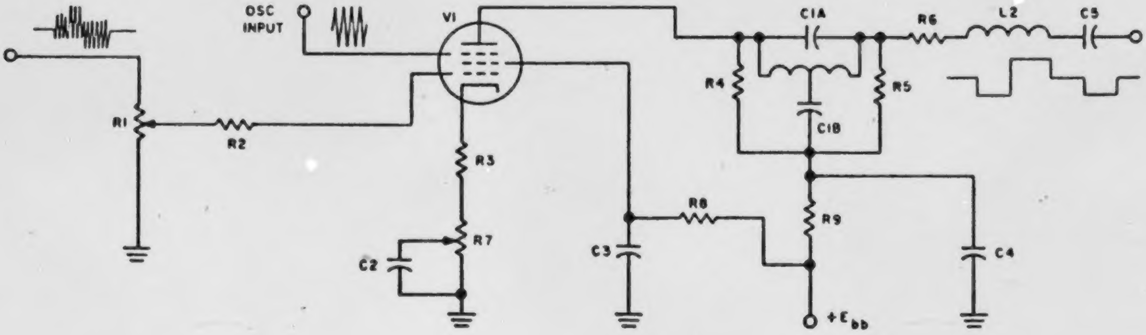

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Figure 7-23.–Synchronous chroma detector, pentode type.

signal and reference signal, while no output is obtained at 90 or 270 degrees.

A synchronous detector employing a pentode tube is shown in figure 7-23. Only one tube is shown since the second tube operates in essentially the same manner except for a different output filter bandwidth.

The chrominance subcarrier input signal is applied to grid 1 of pentode tube V1, and the reference oscillator signal, which is a CW sine wave of the same frequency as the chrominance subcarrier, is applied to the suppressor grid (grid 3). Since the suppressor grid is located between the plate and screen grid, it acts as a gate. During the positive half cycle of the reference signal, an increased flow of electrons is attracted to the plate, and during the negative half cycle, plate current flow is effectively cut off. With no input signal applied to grid 1 and the reference signal applied to grid 3, the positive and negative plate voltage excursions are equal and they average out to zero. Thus, during the periods of time that no input signal is present on the control grid, such as during the reception of monochrome signals, there is no plate output and the coupling capacitor, C5, charges to the average plate voltage value, establishing the zero axis.

When an in-phase signal is applied to grid 1 while the reference signal is applied to grid 3, both voltages add and produce a larger plate current flow. Thus, a higher plate voltage drop occurs in the plate load and a negative output voltage is developed. When the input signal is out-of-phase with the reference signal, a lower-than-normal plate current is produced. With the lower-than-normal voltage drop across the plate load, the average plate voltage increases and effectively produces a positive output.

When the input signal is either 90 or 270 degrees out-of-phase with the reference signal, the input and reference signal voltage maximums occur at opposite times. Hence, when one signal is at a maximum, the other is at a minimum or zero. Thus, the circuit behaves as if only one signal is applied (the reference voltage with no input signal), and the average output is zero. Between the angles of zero degrees and 90 degrees, and between 90 degrees and 180 degrees, the output varies in accordance with the cosine of the phase angle difference. A similar situation exists between 180 and 270 degrees, and between 270 and 360 degrees, except that the output polarity is reversed.

Another circuit that provides for the low-level detection of chrominance signals is the synchronous diode detector of figure 7-24. The G-Y color difference signal is matrixed at the detector by combining proportionate amounts of the B-Y and R-Y difference signals. Since both the R-Y and B-Y detectors function in the same manner, the operation of the B-Y detector in the simplified circuit shown in figure 7-25 will be used in the explanation.

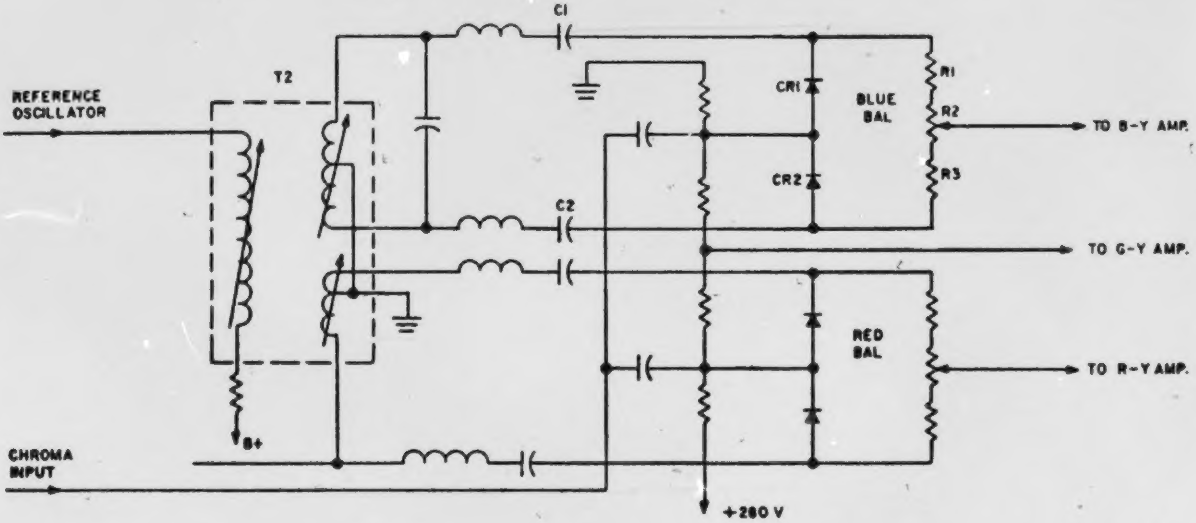

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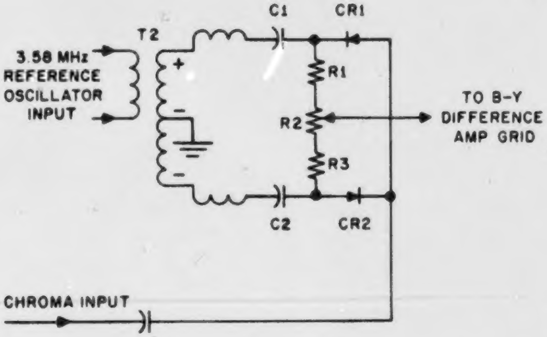
Figure 7-24.—Low-level diode detector.


C1
CR1
T2
3.58 MHz REFERENCE OSCILLATOR INPUT
+
−
−
R1
R2
R3
TO B-Y DIFFERENCE AMP GRID
C2
CR2
CHROMA INPUT

40.253

Figure 7-25.—B-Y synchronous diode detector, simplified schematic.

The reference oscillator signal is applied to the primary of transformer T2 (fig. 7-25) and coupled into the secondary. The reference signal undergoes a 180-degree phase shift due to transformer action and is applied to the series-connected diodes CR1 and CR2. Diode CR1 conducts when a negative signal is applied to its cathode. Simultaneously, a positive signal is present at the opposite end of the secondary and CR2 conducts in an opposite direction. The equal but opposite currents flowing through the diodes cancel out and produce zero output at the control arm of R2. The chroma signal arriving from the chroma amplifier is applied to the diodes in parallel and is detected by each diode during the conduction cycle of each diode. Diode CR1 develops a positive voltage proportional to the sum of the in-phase reference signal and the chroma signal, and diode CR2 develops a negative voltage proportional to the sum of the 180-degree out-of-phase reference signal and the chroma signal.

The preceding chroma detectors are commonly referred to as low-level detectors. Low-level detectors characteristically produce low-strength chrominance signals which must be matrixed and amplified by color difference amplifiers before being applied to the CRT control grids. However, high-level detector circuits have been designed that are capable of demodulating chroma information and applying the detected signals directly to the CRT. A distinct advantage of the high-level detection arrangement is that several critical adjustments and an additional stage of amplification are eliminated. The use of fewer circuit components

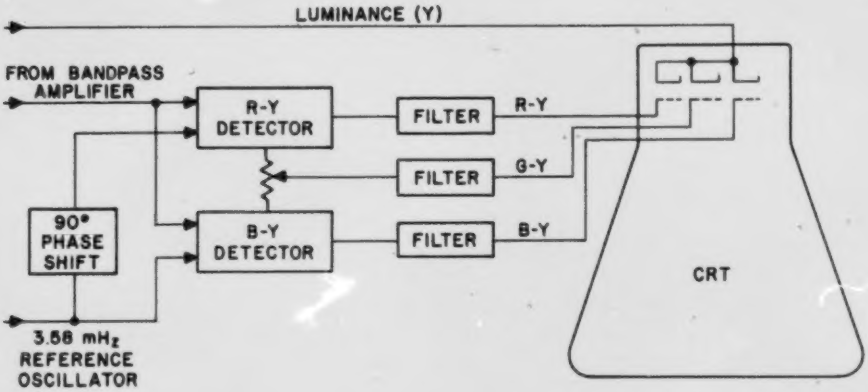


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Figure 7-26.–High-level detection block diagram.

and the simplicity of operation make the use of high-level demodulators desirable.

The block diagram of a high-level detector is shown in figure 7-26. The R-Y and B-Y color difference signals are developed by high gain tubes (usually pentodes) and are applied directly to the CRT control grids. The matrixing required to develop the G-Y color difference signal is usually accomplished in the detector circuits by sampling proportionate amounts of the B-Y and R-Y tube currents through a common resistor or voltage divider arrangement.

MATRIX AND COLOR DIFFERENCE AMPLIFIER CIRCUITS

Matrix circuits are designed to reassemble the chrominance signals to form the original camera output signals. The signals corresponding to the camera video signals are combined with the luminance signal to produce a replica of the televised scene on the face of the CRT. Matrix circuits take on many forms and the particular circuit used in any one individual receiver depends upon the receiver design. At the transmitter, the luminance signal (E_Y) and chrominance signals (E_I and E_Q) were formed by combining proportionate parts of the red, green, and blue camera tube outputs. It would seem, then, that to reverse the process a similar matrix should be used at the receiver. At the receiver, however, the chrominance signals are demodulated to form color difference signals of R-Y and B-Y, rather than the transmitted chrominance signals of E_I and E_Q. (The reason is due to the economic advantages of using equiband circuits.) As a general rule, the luminance (E_Y) signal is combined with the color difference signals in the color CRT; however, this again is determined by receiver design.

The circuit shown in figure 7-27 illustrates the matrixing arrangement used in the majority of present day color receivers. The R-Y and B-Y color difference signals are directly obtained as a result of demodulation, and matrixing is only required to develop the G-Y color difference signal. The formation of the G-Y color

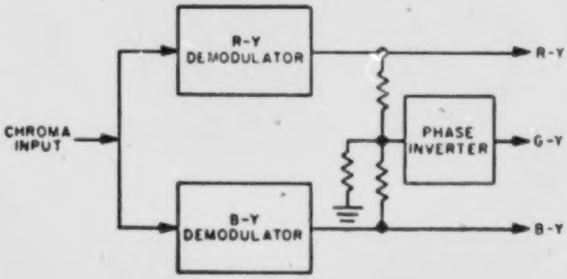

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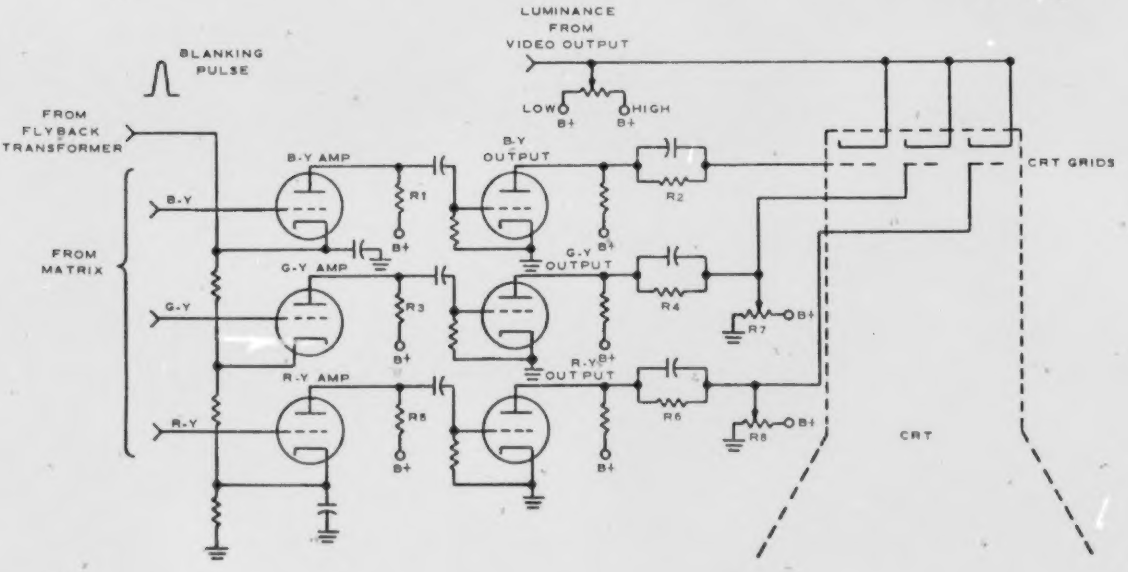
Figure 7-27.–Matrix of R-Y and B-Y to form G-Y.

difference signal is usually accomplished by applying the R-Y and B-Y color difference signals to a voltage divider arrangement and sampling a portion of each signal. The resulting signal is applied to a phase inverter to obtain the G-Y color difference signal.

Another function of matrixing is to restore the original balance between the R-Y and B-Y color difference signals. To regain the original balance, the B-Y color difference signal must be increased 1.78 times with respect to the R-Y difference signal. Although this is usually accomplished by providing additional gain in the B-Y demodulator or color difference amplifier, the correct ratio may in some instances be regained by matrixing.

The preceding paragraphs have described the operation of circuits used to form color difference signals of R-Y, B-Y and G-Y. The color difference signals, depending upon their amplitude, are either applied directly to the control grids of the cathode ray tube (high-level demodulation) or to color difference amplifiers for amplification (low-level demodulation). An example of the latter method is illustrated in figure 7-28. Before examining the operation of this circuit, it may be helpful if you review the operation of the color cathode ray tube.

The three color difference signals, as they arrive at the control grid of their respective amplifier, are still not in the form of original camera signals for the red, green, and blue camera tubes. The signals represent the red camera output minus luminance and the blue camera output minus luminance, etc. To produce the televised scene, the difference



40.258

Figure 7-28.—Color difference amplifier schematic diagram.

signals, which contain only the hue and saturation components of the televised scene, must be combined with the luminance component. This combing action may occur at the picture tube by applying a positive luminance signal to the cathode of each electron gun and by applying the color difference signal to the control grids, or it may take place in external matrix circuits. The latter method, pre-picture tube addition, is seldom employed in modern color receivers and consequently it is not explained here. The first method, picture tube addition, uses the electron stream of each gun to combine the hue, saturation, and luminance of the televised scene.

As shown in figure 7-28, the delayed luminance signal (Y) arrives from the video output tube and is applied directly to the parallel connected cathodes of the CRT. All three cathodes are operated at the same potential and all receive the luminance signal simultaneously. The cathode is characteristically operated at a higher voltage than are the control grids. This operating voltage is dependent upon the setting of the "brightness" control.

Notice that a blanking pulse is applied to the cathode of each color difference amplifier. The blanking pulse is developed by the horizontal flyback transformer and serves to simultaneously cut off the color difference amplifiers and picture tube during the retrace interval.

The plates of the color difference amplifiers are directly coupled to the control grids of the CRT through resistors R2, R4 and R6; consequently, a change in plate voltage of any one amplifier will affect the emission of its respective electron gun. The "blue" and "green" electron guns are biased at a prescribed voltage level with respect to the "red" electron gun by variable resistors R7 and R8. These bias controls, known as the blue and green drive controls, are adjusted during the reception of monochrome signals (equal output from each color difference amplifier) and serve to compensate for efficiency differences between the red, blue, and green phosphor coatings. These controls also serve to balance the grid-voltage and beam characteristics of each gun. For instance, the red phosphor coating is characteristically less efficient than the green or blue phosphor coating. If all three phosphor coatings are bombarded with the same number of electrons, the reproduced image on the face of the CRT will appear bluish-green rather than white. Therefore, the conduction from the green and blue guns must be retarded slightly to obtain proper color balance.

Color difference signals are coupled from the matrix circuit and applied directly to the control grid of each color difference amplifier. Assuming monochrome reception for the moment, the amplitude of each color difference signal will be equal. The equal grid signals cause the plate voltage of each amplifier to vary by equal amounts to establish equal voltages on each grid of the CRT. Since the grid voltages are equal, the emission of each electron gun will be controlled by the luminance signal applied to the cathode of each gun. Thus during monochrome reception, the three-gun CRT behaves much like a conventional single-gun monochrome CRT.

Now assume that a saturated red scene is being viewed by the station camera. The receiver demodulators detect the chrominance signal and a signal of maximum amplitude will be present on the grid of the R-Y color difference amplifier. Since the televised scene has an absence of blue and green colors, the signal on the grid of the B-Y and G-Y color difference amplifier will be at minimum amplitude. The high-amplitude R-Y signal applied to the R-Y color difference amplifier will cause the average plate voltage of the amplifier to decrease, thus reducing conduction of the R-Y output amplifier and increasing its average plate voltage. This increased voltage is directly coupled to the control grid of the "red" electron gun and conduction will increase to maximum, causing the red phosphors on the face of the CRT to illuminate. By contrast, the average plate voltage of the B-Y and G-Y output amplifiers will be at a lower potential since the B-Y and G-Y color difference amplifiers are effectively cut off. This plate voltage, considerably lower than that of the R-Y output amplifier plate, is coupled to the "green" and "blue" electron guns and forces these guns to cut off. Consequently, the blue and green phosphors are not excited while the "red" phosphor is receiving maximum excitation. Thus, the televised scene is reproduced on the face of the CRT.

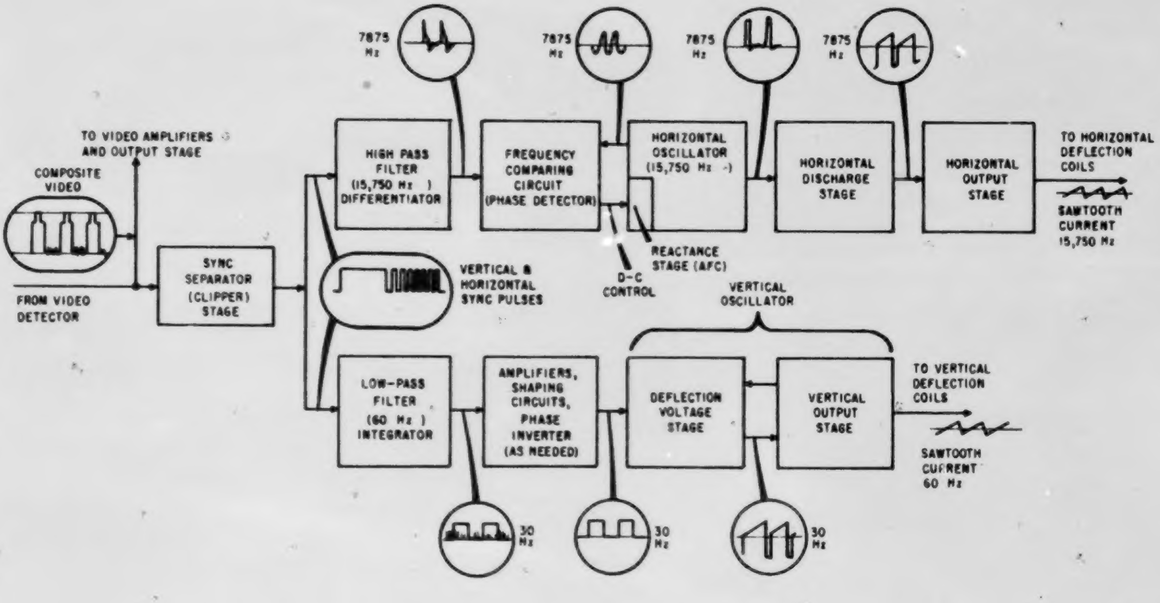
SYNCHRONIZING CIRCUITS

The previous discussion on closed circuit TV was focused primarily on delivering the video signal to the picture tube. Equally important, from the point of view of overall receiver operation, is the system by which the various circuits are synchronized with those at the transmitter and made to function together to produce the desired picture. Refer to figure 7-19 for an overview of the system. As previously stated, the blanking pulses and the horizontal and vertical synchronizing (sync) pulses are amplified in the various stages along with the video information. The sync separator, automatic gun control, and sweep circuits are virtually the same in color receivers as in monochrome receivers.

The detected composite video signal (containing synchronization pulses, blanking pulses, and video) is applied to the control grid or cathode (depending on phase) of the picture tube. The video information intensity modulates the scanning electron beam, producing varying degrees of black through white information on the screen. The blanking pulses cut the picture tube off to prevent a visual indication of retrace. The sync pulses are present but have no effect since they are present during the time the picture tube is cut off and only drive the tube beyond cutoff.

After detection and amplification, the composite video signal is also fed to a sync separation or clipper stage. The vertical and horizontal sync signals are removed from the composite video signal and filtered. Following this, the pulses are amplified and reshaped according to the needs of the synchronization and sweep systems. A block diagram of the synchronization circuits is shown in figure 7-29 with the associated pulse waveforms.

The horizontal sync signal fires the horizontal oscillator at exactly the right instant to maintain the proper synchronization between the horizontal sweep in the receiver picture tube


7875 Hz
7875 Hz
7875 Hz
7875 Hz
TO VIDEO AMPLIFIERS AND OUTPUT STAGE
COMPOSITE VIDEO
FROM VIDEO DETECTOR
SYNC SEPARATOR (CLIPPER) STAGE
HIGH PASS FILTER (15,750 Hz) DIFFERENTIATOR
FREQUENCY COMPARING CIRCUIT (PHASE DETECTOR)
HORIZONTAL OSCILLATOR (15,750 Hz -)
HORIZONTAL DISCHARGE STAGE
HORIZONTAL OUTPUT STAGE
TO HORIZONTAL DEFLECTION COILS
SAWTOOTH CURRENT 15,750 Hz
REACTANCE STAGE (AFC)
D-C CONTROL
VERTICAL & HORIZONTAL SYNC PULSES
VERTICAL OSCILLATOR
LOW-PASS FILTER (60 Hz) INTEGRATOR
AMPLIFIERS, SHAPING CIRCUITS, PHASE INVERTER (AS NEEDED)
DEFLECTION VOLTAGE STAGE
VERTICAL OUTPUT STAGE
TO VERTICAL DEFLECTION COILS
SAWTOOTH CURRENT 60 Hz
30 Hz
30 Hz
30 Hz

7.104

Figure 7-29.—Block diagram of synchronizing circuits.

and the horizontal sweep in the transmitter camera tube. The output of the horizontal oscillator is formed into a sawtooth waveform; it is then amplified and applied to the horizontal deflection coils.

The vertical sync signal fires the vertical oscillator at the right instant to maintain the proper synchronization between the vertical sweep in the receiver picture tube and the vertical sweep in the transmitter camera tube. As in the case of the horizontal oscillator output, the vertical oscillator output is formed into a sawtooth wave (modified into a trapezoidal form); it is then amplified and applied to the vertical deflection coil.

SYNC SEPARATORS

Sync separation, or sync clipping, may be accomplished by the use of circuits employing tubes or transistors. A simplified circuit of a diode sync separator is shown in figure 7-30. During the time the sync voltage is applied to the input, the diode plate is positive with respect to the cathode, and capacitor C is charged through the low resistance of the conducting diode. Between pulses, capacitor C discharges through R and thus maintains a negative bias between plate and ground; this cuts off all signals up to the blanking level. The bias is maintained at approximately the blanking level, and only the sync signal causes pulses of current to flow through RL, across which the output is taken.

The output pulses consist of the horizontal sync pulses, the equalizing pulses, and the serrated vertical sync pulses. These pulses are fed to filter circuits that separate the vertical sync pulses from the horizontal sync pulses.

The simple diode separator is easily converted into a transistor sync separator. This is possible because the transistor-input terminals (base-emitter terminals) are actually a diode. The transistor merely adds gain to the basic diode sync separator. Figure 7-31 shows a simplified transistor sync separator.

The problems involved in removing (sync clipping) the sync signals from the composite signal, and in amplifying, separating, and utilizing those signals to control the horizontal and vertical oscillators are treated only in a general way in this section. There are many methods of solving these problems, and therefore a detailed treatment of each method is not possible in this training manual.

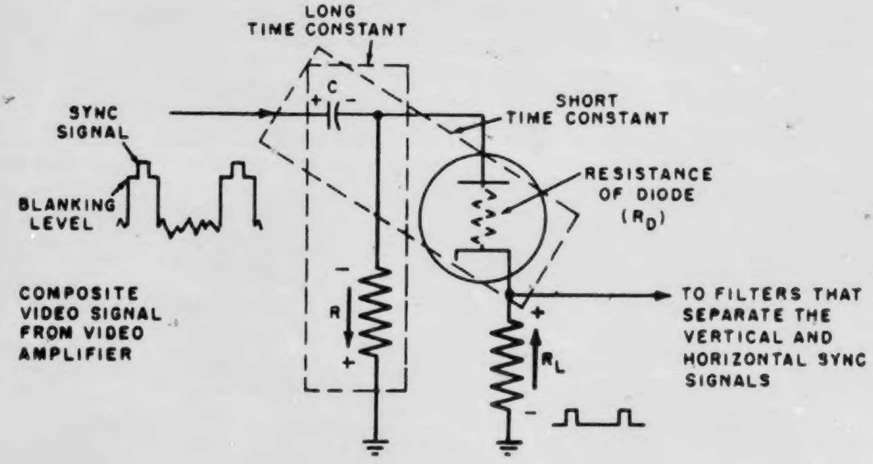
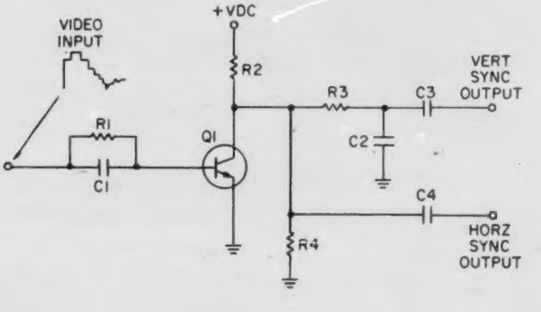

LONG TIME CONSTANT
C
+
-
SYNC SIGNAL
SHORT TIME CONSTANT
RESISTANCE OF DIODE (R_D)
BLANKING LEVEL
COMPOSITE VIDEO SIGNAL FROM VIDEO AMPLIFIER
R
-
+
+
R_L
-
TO FILTERS THAT SEPARATE THE VERTICAL AND HORIZONTAL SYNC SIGNALS
7.105

Figure 7-30.—Diode sync separator.



244.205

Figure 7-31.—Transistor sync separator.

Separation of Vertical and Horizontal Sync Pulses

Because the repetition rate of the vertical sync pulses is 60 pulses per second and that of the horizontal sync pulses is 15,750 pulses per second, they can be separated by filters.

One filter, the high-pass filter, is used to pass and shape the trigger voltages for the horizontal oscillator (a multivibrator or blocking oscillator) as shown in figure 7-32. The circuit in this figure has a short time constant with respect to the period (width) of the horizontal pulse. The output signal is developed across R.

The leading edge of the square-wave input pulse causes a rapid charge of C through R. The trailing edge causes an equally rapid discharge of C through R. The flow of charge and discharge currents through R causes the sharp spikes of output voltage, as shown in figure 7-32. Only one spike in each pair (for example, the positive spike) is needed to trigger the horizontal oscillator. The other spike of the pair occurs at a time when the oscillator is insensitive to triggering pulses.

The low-pass filter used to pass and shape the trigger voltages for the vertical oscillator (a multivibrator or blocking oscillator) is shown in figure 7-33. The RC time constant is long with respect to the width of each serration in the

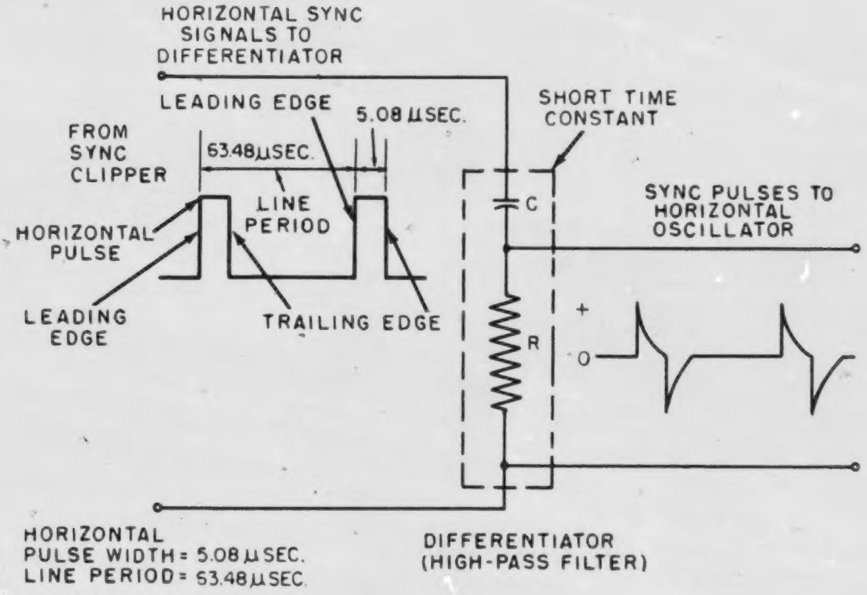


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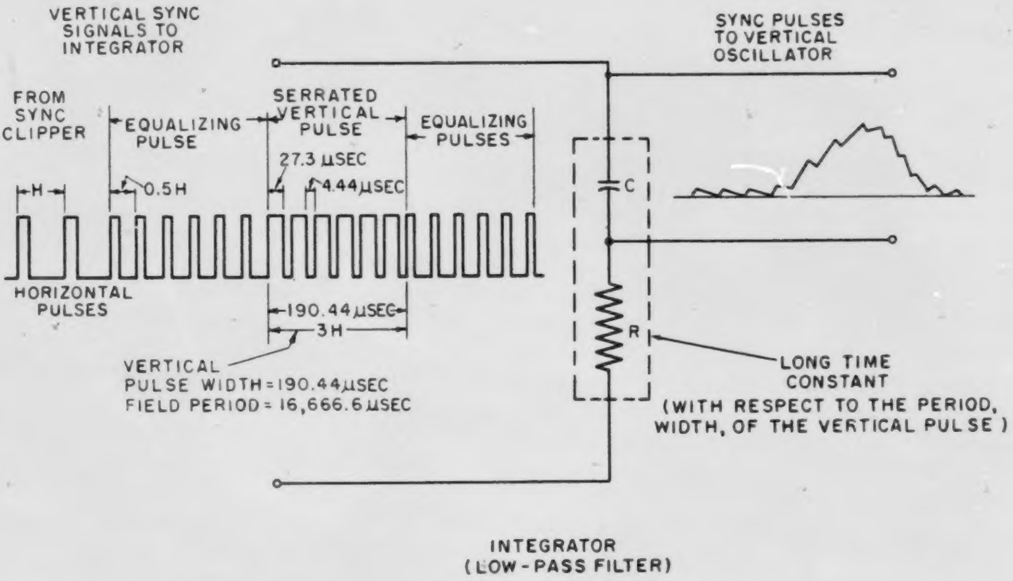
Figure 7-32.—High-pass filter for horizontal sync.


VERTICAL SYNC SIGNALS TO INTEGRATOR
SYNC PULSES TO VERTICAL OSCILLATOR
FROM SYNC CLIPPER
EQUALIZING PULSE
SERRATED VERTICAL PULSE
EQUALIZING PULSES
27.3 μSEC
H
0.5H
4.44μSEC
C
HORIZONTAL PULSES
190.44μSEC
3H
R
VERTICAL PULSE WIDTH=190.44μSEC
FIELD PERIOD=16,666.6μSEC
LONG TIME CONSTANT
(WITH RESPECT TO THE PERIOD, WIDTH, OF THE VERTICAL PULSE)
INTEGRATOR
(LOW-PASS FILTER)

7.107

Figure 7-33.—Low-pass filter for vertical sync pulses.

vertical pulse. Because of the long time constant in the integrator circuit, C does not have time to discharge during the interval between serrations. However, the RC time constant is short compared to the period of the combined vertical serrated pulses. Thus, C charges up to the peak value during the time the vertical serrated pulse is applied (190.44 μsec in the figure) and discharges to zero before the next horizontal pulse arrives.

The circuit is relatively insensitive to the longer, low-repetition-rate pulses that control the vertical oscillator. The reason is clear when you note that the time constant (with respect to the width of each horizontal pulse) of the differentiator circuit is short and the output is taken across the resistor.

Because of the long time constant (with respect to the width of each horizontal pulse) of the integrator circuit, the horizontal pulses have very little effect and the equalizing pulses have even less effect. The only pulse that produces a useful output is the serrated vertical pulse. Sixty of these pulses occur each second, 30 for each of the 2 fields. The vertical pulses are serrated to provide the triggering action for the horizontal oscillator during the vertical retrace period.

SWEEP CIRCUITS

After being separated and shaped, the horizontal and vertical sync pulses are applied to the horizontal and vertical sweep oscillators, respectively, so they may be triggered at the correct instant to synchronize the receiver with the transmitter. Both the vertical and horizontal sweep oscillators, when fed into the correct circuits, produce current sawtooth waveforms.

The sawtooth waveforms produced by the horizontal sweep oscillator are amplified and applied to the picture tube in a manner that will cause the electron beam to be deflected (swept) horizontally across the face of the tube. Likewise, the waveforms produced by the vertical sweep oscillator cause the electron beam to be deflected from the top to the bottom of the picture tube.

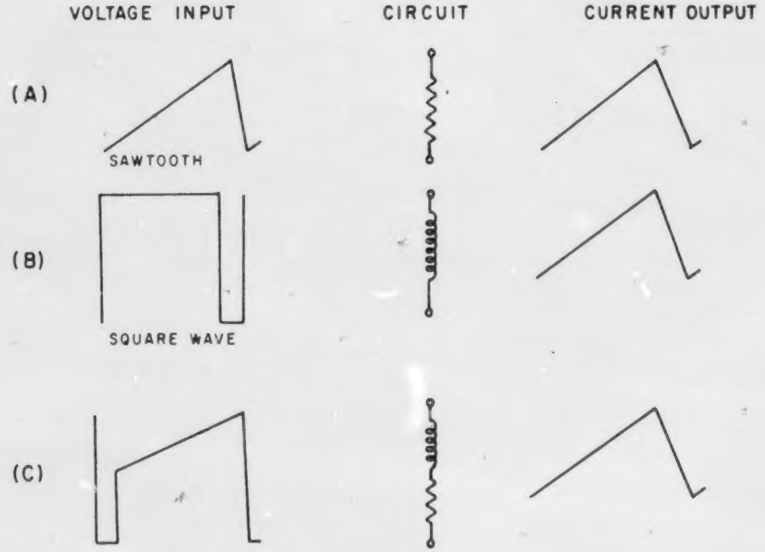
Multivibrators and blocking oscillators are two types of resistance-capacitance oscillators commonly used in the sweep circuits (vertical and horizontal) of television receivers. At this point it may be helpful to review the section describing these oscillators in *Basic Electronics*, NAVPERS 10087 (Series).

In electromagnetic deflection systems, the driving force in the picture tube is a magnetic field. To develop such a field, a sawtooth deflection current is required. Further, due to the inductive action in the output state of a tube-type, vertical-output amplifier, a trapezoidal waveform is required to produce this sawtooth of current. This is illustrated in figure 7-34. To produce a sawtooth of current through an inductive circuit, a square wave of voltage must be applied (B). To produce a sawtooth of current through a resistive circuit, a sawtooth of voltage must be applied (A). To produce a sawtooth of current through an inductive-resistive circuit, both a sawtooth and square wave (trapezoidal wave) must be applied (C).

VERTICAL SWEEP

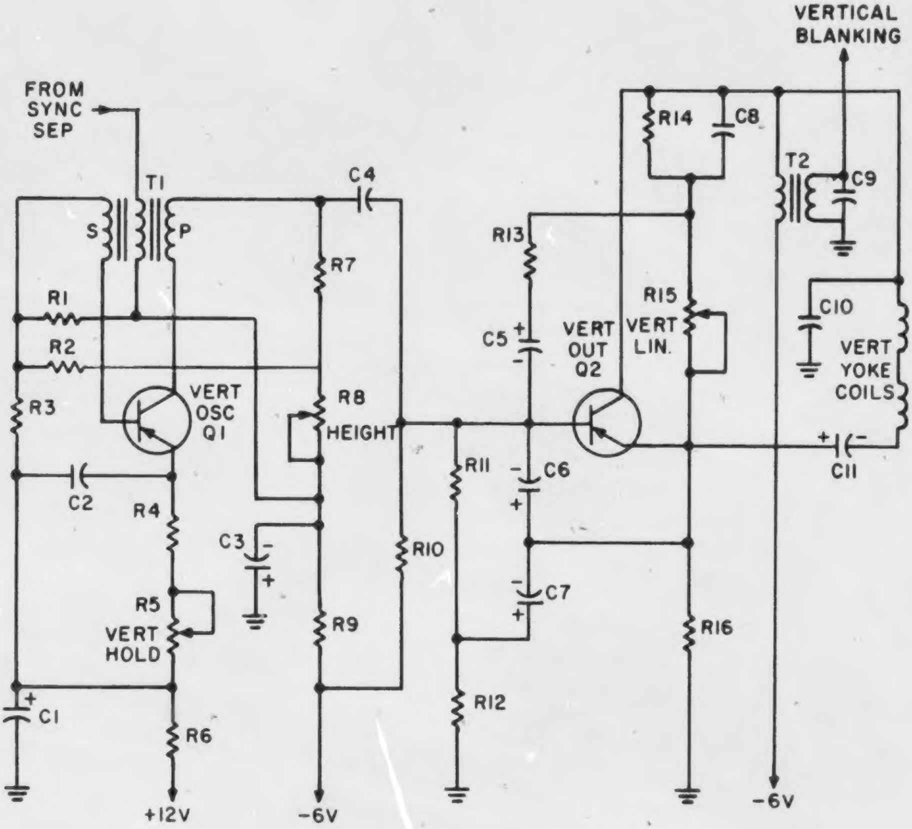
The vertical sweep circuit (fig. 7-35) produces a current which moves the electron beam of the picture tube from the top to the bottom. It should be noted at this point that when transistors are used for the vertical and horizontal output amplifiers, the input wave to the output transistor is generally not trapezoidal but is close to a sawtooth.

The vertical oscillator (Q1) shown in figure 7-35 is a conventional blocking oscillator. The signal from this oscillator is fed to the vertical output stage (Q2) and on to the series-connected vertical yoke coils. Oscillator frequency is determined by the RC time of C2, R4, and R5. The height control, R8, varies the collector bias voltage, thus changing the amplitude of the output signal. Without compensation this could change oscillator frequency since it affects the charging capacitor by changing the amount of charge. Hence, a compensating network is included to prevent this from occurring. R1 is connected from the negative 6 volt supply to the secondary of winding T1, shunting both R8 and R2. The effect of this network is to change the forward bias on the oscillator so that the frequency is shifted in the opposite direction to compensate for any shift caused by the height adjustment.



40.229

Figure 7-34.—Trapezoidal waveform.



244.206

Figure 7-35.–Vertical sweep section.

The oscillator signal is coupled to the base of the output stage through C4. Forward bias for Q2 is provided by the voltage divider network (R10, R11, and R12) in the base circuit. Both emitter and collector currents normally flow. The positive pulse from the vertical oscillator opposes this forward bias and abruptly reduces the emitter-collector current. This period of abrupt current drop is the vertical retrace time and lasts for the duration of the oscillator pulse. C5, C6, and C8 combine to form the sawtooth wave for the vertical trace period. R15, in series with C8, forms a waveshaping feedback circuit between the emitter and collector of Q2. C5 and R13 perform the same function between the output and the base.

Vertical output transformer T2 is a voltage step up device with the secondary providing sufficient voltage for vertical retrace blanking. C9 is connected from the secondary to ground to prevent any horizontal pulses from distorting the vertical output. The vertical yoke coils, which are actually the collector ac load, are returned to the emitter of Q2 through C11 to isolate the yoke from dc. C10, connected from the collector to ground, provides further filtering.

AUTOMATIC FREQUENCY CONTROL (AFC)

The use of incoming sync pulses to trigger and control the vertical and horizontal sweep oscillators is the simplest, most economical, and most direct method of controlling the motion of the electron beam in a television. This simple, direct system would be satisfactory if it were not for the presence of noise pulses that may cause the oscillators to fire at the wrong time. When the vertical oscillator fires at the wrong time, the picture is not properly synchronized vertically; the picture bounces, or moves in jumps upward or downward across the screen. When the horizontal oscillator fires at the wrong time, the picture is not properly synchronized horizontally; the picture tears or becomes streaked, giving the appearance the picture is jumbled.

Although noise pulses may affect the operation of both the vertical and the horizontal oscillators, a far worse effect is felt by the horizontal oscillator. The long time constant of the vertical filter makes it insensitive to the short bursts of noise energy, and the effect on the vertical oscillator is not generally objectionable. In closed circuit TV, noise from electrical machinery can be just as destructive as atmospheric noise in a conventional home TV system.

The short time constant of the filter that feeds the sync pulses to the horizontal oscillator permits the passage of short bursts of noise energy. Consequently, it is necessary to employ a control circuit that effectively isolates the horizontal oscillator from the effects of noise pulses, and at the same time permits the sync pulses to assume control.

Two systems that isolate the horizontal sweep oscillator from the effects of noise bursts are shown in the block diagrams of figure 7-36. In the system shown in part (A), two signals are applied to the frequency discriminator. They are horizontal sync signals and horizontal sweep oscillator signals. The frequency discriminator compares the frequency (or phase) of these signals and produces an output dc voltage that depends on the difference between the frequencies (or phase) of the two signals. The output voltage, normally varying at a relatively slow rate, is fed via a low-pass filter to the grid of the reactance tube. This tube functions in such a manner that its output changes the frequency of the horizontal sweep oscillator to maintain its frequency exactly the same as that of the incoming horizontal sync pulses. Reactance tubes and frequency discriminators are discussed in *Basic Electronics*.

The second method of isolating the horizontal sweep oscillator from noise bursts is

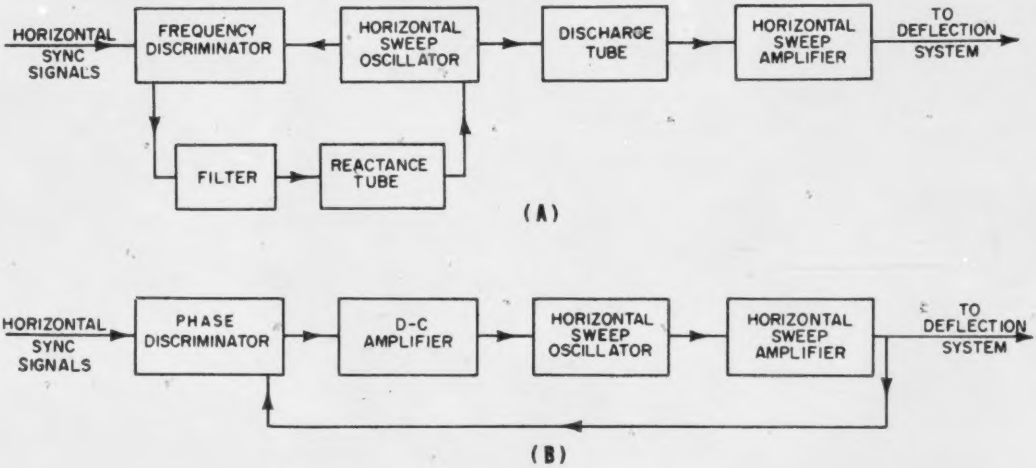
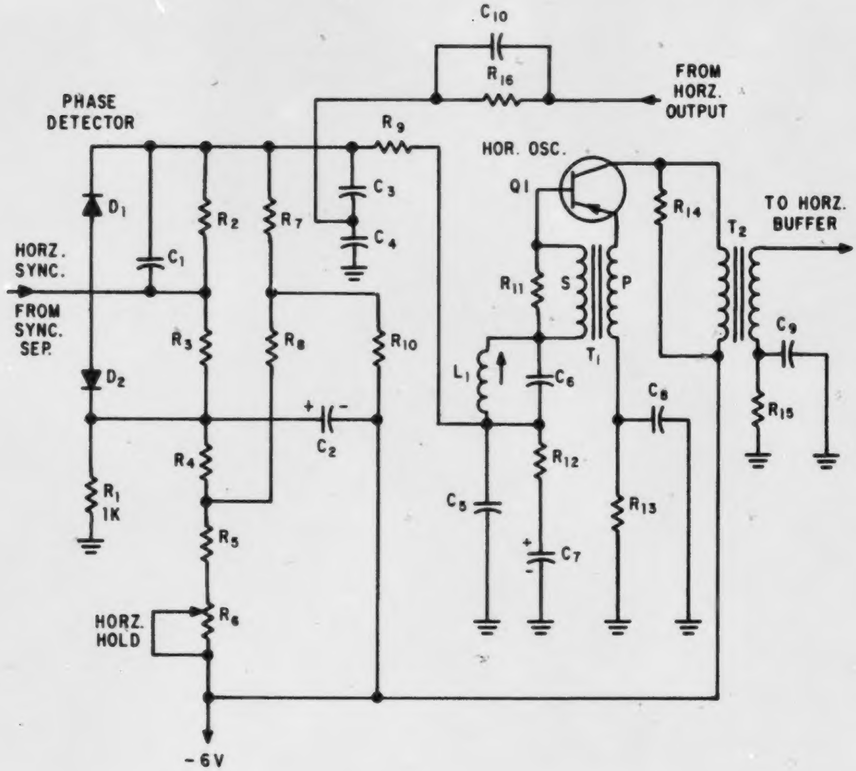


Figure 7-36.—Systems of horizontal sync control.



244.207

Figure 7-37.–Horizontal Sweep (Part A).

shown in figure 7-36 (B). As in the previous system, a frequency (or phase) discriminator is used. It compares the sync-signal input from the filter or sync amplifier with the input feed-back from the horizontal sweep amplifier and produces a dc output that is proportional to that difference. The manner in which this dc output is amplified and used causes the frequency of the horizontal sweep oscillator to lock in step with the incoming sync signals. This method is described in the following section.

HORIZONTAL SWEEP

In general, the same basic types of deflection oscillators found in the vertical deflection system are also used in the horizontal system. These are the blocking oscillator and the multivibrator types that employ both tubes and transistors.

Figure 7-37 is a simplified schematic diagram of the phase detector and oscillator portion of the horizontal sweep section of a transistorized TV receiver. The phase detector samples a feedback signal from the horizontal output stage and compares its phase with the incoming horizontal sync pulses. Any phase difference results in an appropriate dc voltage from the phase detector being applied to the oscillator. This signal then causes the oscillator to change its frequency.

When the pulses are in phase, the outputs from D1 and D2 are equal and opposite, thus no dc control voltage is produced for the base of the oscillator. When the oscillator frequency is low or lagging the sync, D1 conducts more heavily than D2, producing a positive control voltage at the output. This positive voltage, applied to the base of Q1, increases the frequency of oscillations. When the frequency of the oscillator is high or leading the sync, D2 conducts more heavily, producing a negative control voltage which lowers the frequency of the oscillator.

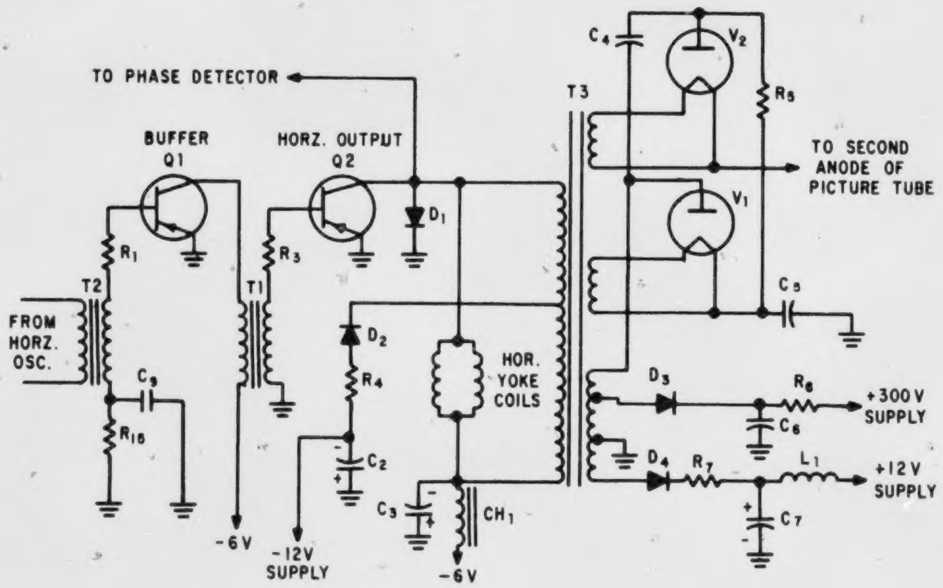
The horizontal oscillator, Q1, is a blocking oscillator that operates similar to the one in the vertical section. Transformer T1 is the blocking-oscillator transformer and L1 is a stabilizer coil.

Stabilizing coil L1 is in series with the secondary of T1 and is shunted by C6. When an abrupt current change through the coil occurs due to oscillator action, C6 discharges through the coil. The resulting magnetic field around the coil induces a voltage that recharges the capacitor, but to a lower level than previously. Thus, the oscillations are damped out. The timing of this ringing action is adjustable to the point where it helps fire the oscillator at a constant rate, thus providing a degree of stability.

Horizontal hold control R6 establishes the bias on the base of Q1 to bring the oscillator within control range of the phase detector. Since the setting of R6 can affect the balance of the phase detector, isolating and compensating resistors R4, R7, R8, and R10 are incorporated to minimize this effect. The horizontal output pulse that is fed back to the phase detector is shaped into a sawtooth wave by C4, C10, and R16.

The balance of the horizontal sweep circuits (buffer, horizontal output, and high voltage) are shown in figure 7-38. The positive output pulse of the oscillator is inverted by interstage transformer T2 and applied to the base of Q1 as a negative pulse. The buffer is normally cutoff since there is no forward bias from the base to emitter.

The negative pulse at the base of the buffer amplifier drives the stage into conduction. RC network C9 and R15, however, develops a base bias from the signal current which permits conduction only on the peaks of the pulses. Since a common emitter circuit is used, a positive pulse appears at the collector. The



244.208

Figure 7-38.—Horizontal sweep (Part B) and high voltage.

positive signal from the buffer is transformer-coupled through T1 to the base of horizontal output transistor Q2.

The output transistor is a special power type transistor capable of handling the relatively high-power requirements of the stage. At the collector, a positive horizontal sweep pulse appears and is directly coupled to the horizontal yoke coils connected in parallel. The horizontal pulse causes a relatively linear sawtooth current in the yoke coils. Yoke damping action is provided by diode D1 which dampens any self-resonant oscillations of the yoke.

A tap on the primary of horizontal output transformer T3 is used to develop a -12 volt supply through diode D2. Two taps on the secondary of the same transformer provide +12 and +300-volt power supplies through their respective diode rectifiers and filters.

When the horizontal output transistor is conducting, collector current is drawn through the primary of T3, and the collector voltage declines from -6 volts in a positive direction, producing a positive horizontal sweep pulse. The heavy current flow through the transformer primary causes high peak-voltage pulses to be developed across the high-impedance secondary winding. These pulses are applied to the plate of the first high-voltage rectifier, V1. The rectifier current charges C5 to approximately 5,000 volts. This voltage is applied to the plate of the second rectifier, V2, through R5. Capacitor C4 also couples the high-voltage pulse from the transformer secondary to the plate of V2, thus adding to the high dc voltage applied through R5. As a result, approximately 10,000 volts appear at the filament of V2. This is the high voltage that is applied to the second anode of the picture tube (kinescope). Voltages up to 30 Kv are found in color TV high-voltage systems.

TV POWER SUPPLIES

As you have just seen, the power supply requirements of a television receiver are considerably different from those of a radio receiver. Because of the high-voltage requirements of the CRT, TV receivers employ two power supplies–high voltage and low voltage. The high-voltage section was discussed in the previous section. A typical transistorized low-voltage supply will now be discussed.

New solid-state TV receivers utilize both low-voltage and high-voltage transistors. This requires a large assortment of voltages. Since transistors are low-impedance devices, they work best when driven by voltages from low-output-impedance supplies.

A power supply that provides multiple low-impedance output voltages is shown in figure 7-39. The -20 and +24 output voltages drive most of the low-level stages in the set. A zener regulator is used for the +24 volt supply, and an active filter is employed in the -20 volt supply. The +100 volt output services the output stages of the following sections: video, vertical, horizontal, and audio. Note the wiring arrangement of the two full-wave rectifiers. This is done in some receivers so that part of the diode can be physically connected to ground. The ground is then used as a heat sink, eliminating the need for an insulator between ground and the rectifier body.

Generally speaking, color TV power supplies are slightly larger and more complex than those found in black and white sets. This is due in part to the power required by the extra circuits in the color sets and the automatic degaussers in the B+ line.

Figure 7-40 shows a typical power supply used in large-screen color TV receivers. This type of power supply, with its numerous output voltages, feeds both transistors and tubes. Most of the transistors receive their power from the +20 volts developed by the active filter. After a little extra filtering, this same +20 volts is sent to the tuner. R7 is used to adjust this output. All of the tube heater filaments, except the picture tube, receive their power from the same output winding that provides the +20 volt outputs. The picture tube heater is on a separate winding that is biased to +140 volts to prevent cathode to heater shorts.

The +290 volt B+ supply has a degaussing circuit in series with it. A thermistor and varistor control the current in the degaussing coil. As the

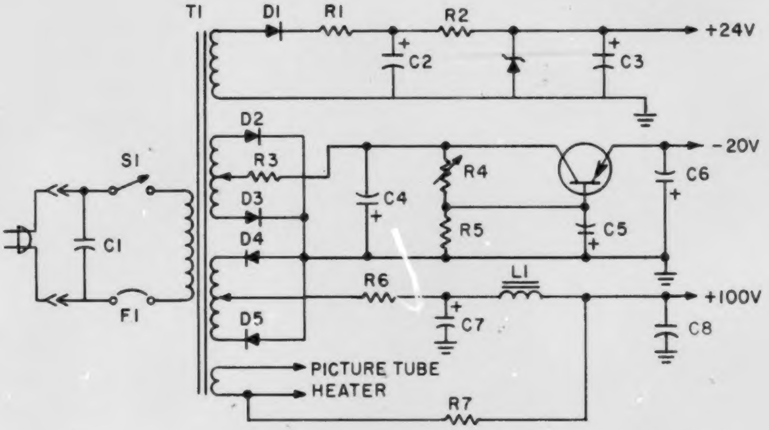


Figure 7-39.—Black and white, solid state power supply. 244.209

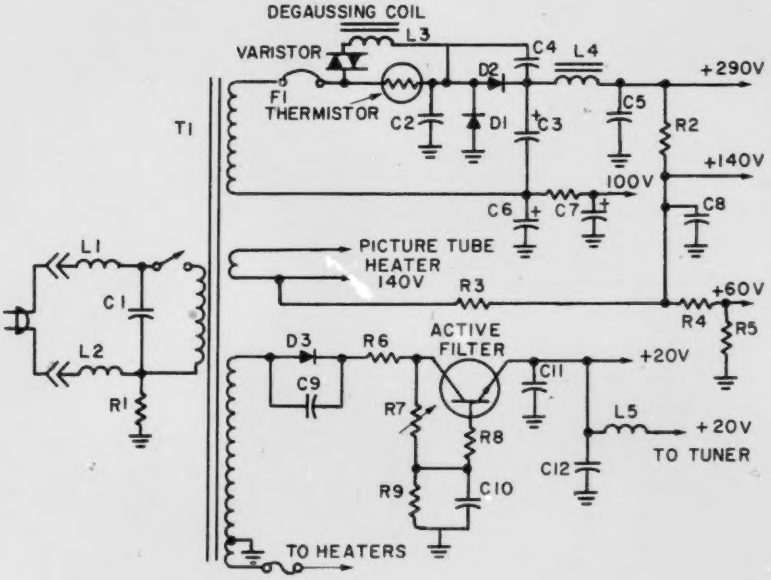


Figure 7-40.—Color, solid state power supply. 244.210

circuit warms up, the thermistor decreases in resistance and the varistor increases in resistance. The net result is a surge of current through the degaussing coil for a few seconds before the set warms up. Very little current then flows through the coil during normal receiver operation. The +290 volt supply uses a half-wave voltage doubler. Capacitors C2 and C4 are across the diodes for transient protection. This feature gives the diodes a much longer life.

SYSTEM ANALYSIS

The key to effective maintenance is the ability to analyze the complete system in operation, determining how each section affects the other. In troubleshooting a television system, symptoms can be obtained by viewing the picture tube and listening to the sound system. A summary of the overall system operation is the first step in analyzing troubles.

SUMMARY

The objective in television is to convert light reflections from an object into equivalent electrical impulses so, with the help of control and scan circuits, the image of the object may be reproduced at the receiver.

The complete details of a picture or object cannot be transmitted (with the system currently being used) simultaneously. They must be sent bit by bit in rapid sequence so, with the aid of persistence of vision, the picture may be seen as a whole. This method of transmitting a picture in parts, or bit by bit, is called scanning. (Chapter 6, figure 6-3.) In the United States, scanning (both in the camera tube and in the picture tube) is from left to right and from top to bottom. In order to avoid objectionable flicker without increasing the horizontal scanning speed, and without increasing the bandpass requirements of the composite TV signal, each of the thirty complete frames that are scanned out each second is divided into two fields. That is, during the first field every other line is scanned, and during the second field the lines missed during the first field are covered. This system of scanning is called interlaced scanning. (Chapter 6, fig. 6-4.) Essentially the same net effect, as far as the viewer is concerned, is obtained by the shutter action in moving-picture projectors.

In one type of camera tube, the electron beam, under the influence of the deflection coils, scans across the mosaic, which is composed of minute globules of a light-sensitive compound. The individual globules have charges that are proportional to light incident on them. The electron beam neutralizes the charges, and the resultant instantaneous electron flow, from the common backplate of the mosaic through a resistor, develops an instantaneous signal voltage. The succession of signal voltages is amplified, and along with the blanking and synchronizing voltages is used to modulate the video carrier wave.

Blanking voltages are used to blank out the electron beam in both the camera and the picture tubes during the horizontal and vertical retrace times. Synchronizing voltages are injected during the blanking periods to synchronize the horizontal sweeps and the vertical sweeps at the transmitter and the receiver.

Because an image may contain a vast amount of detail, a wide range of frequencies must be transmitted for satisfactory viewing. Therefore, the transmitter and receiver circuits must be capable of passing, without distortion, a wide range (about 4.5 MHz) of frequencies.

Although the audio signals are transmitted along with the video signals, the audio and video systems are essentially separate systems. The video carrier is amplitude modulated and the sound carrier is frequency modulated.

Because the television signals present at the receiving antenna are often very weak, it is necessary to use a high-gain antenna. Out-of-phase signals may arrive (after reflection) at the rear of the antenna, and may make the use of a highly directional antenna desirable. Various types of commercial antennas are available for both the VHF and UHF bands. The UHF antennas are smaller, and therefore elaborate arrays that would be too cumbersome at lower frequencies are sometimes used.

Television "front ends" (tuners) have much in common with radio front ends. However, bandpass considerations, wide tuning range, high frequency operation, and reception in fringe areas have introduced design problems. Front ends are composed of an RF amplifier, a local oscillator, and a mixer. (See fig. 7-2.) The cascode amplifier is a popular television RF amplifier. It produces fairly high gain and introduces very little noise.

A number of tuning methods are used in TV front ends. Rotary switches that connect the correct inductors and capacitors for the desired channel are often employed. In some systems, the "tuned line" is used, and in others the turret tuner is used. The Inductuner, one of the few continuous tuners, tunes over the entire tuning range.

Bandpass requirements, vestigial sideband transmission, and the necessity for trapping out undesired frequencies have introduced problems in the design of video IF amplifiers. Stagger tuning is employed to obtain the desired bandpass. In order to avoid overemphasizing the frequencies adjacent to the video carrier, the video IF stages are adjusted so the video carrier falls approximately halfway down on the slope of the video IF bandpass. Resonant trap circuits are used to absorb and dissipate the energy contained in the undesired frequencies.

The video detectors commonly employed are electron tubes or crystal diodes. (See fig. 7-9.) The output of the detector may have positive or negative picture phase, depending on the way the diode and elements of the picture tube are connected.

After the video signal has been rectified in the video detector, it is amplified in one or more amplifiers before it is applied to the picture tube. Because a wide band of frequencies must be passed without discrimination, the video amplifiers must be carefully designed. Special high and low frequency compensating circuits must be used to extend the approximate range of frequencies passed from 30 Hz to 4 MHz. In other words, frequency distortion must be eliminated as much as possible. In order to pass the required wide band of frequencies, some form of shunt compensation or series compensation or a combination of both is used. Likewise, phase distortion must be eliminated as much as possible. Phase distortion is reduced by the proper design of the coupling circuits.

The dc component of a pulse waveform must be restored after it has been removed by the passage of the waveform through the coupling capacitor in the video amplifier stage. It is the function of the dc restorer to reinsert the correct dc component at the input of the television picture tube so the correct level of background illumination is maintained. Diode or grid leak restorers are the types often used.

Synchronizing circuits are exceedingly important in TV receivers. These circuits separate the sync pulses from the composite video signal, and in turn separate the horizontal from the vertical sync pulses.

The horizontal sync pulses are used to trigger the horizontal oscillator (a multivibrator or a blocking oscillator) at the correct instant to keep the horizontal sweep of the receiver in step with the horizontal sweep of the transmitter. If the horizontal oscillator does not lock-in properly, the picture gives the appearance of tearing.

The output of the horizontal oscillator is fed to a circuit (for example, a discharge tube), which gives the voltage pulse the proper trapezoidal sawtooth form. The pulse is then amplified and fed to the deflection yoke. It is common practice to utilize the inductive kick due to the horizontal flyback in the output transformer to produce the high voltage for the picture tube. The output transformer has an autotransformer arrangement, which effectively adds the necessary additional inductance. Included in this stage, is the damper tube, which dampens oscillations and provides a higher or boosted B+.

The vertical sync pulses are used to trigger the vertical oscillator (a multivibrator or a blocking oscillator) at the correct instant to keep the vertical sweep of the receiver in step with the vertical sweep of the transmitter. If the vertical oscillator does not lock-in properly, the picture will "roll" downward or "jump" upward.

The pulse from the vertical oscillator is properly shaped, amplified, and fed to the yoke as sawtooth current.

In the intercarrier system, the sound and the video signals are amplified in the same IF system of amplifiers. At the video detector, or in a circuit following the video detector, the sound IF is removed and fed to the sound IF amplifier, which also acts as a limiter. A ratio detector or a discriminator may be used as the FM detector. A gated-beam tube is sometimes used as the FM detector. When this tube is used, the sound IF stage may be omitted. After the FM sound signal has been detected, it is fed to the audio amplifier and the speaker.

UNIT ISOLATION

When troubleshooting a system, the first step is to isolate the probable trouble to one major unit. Figure 7-41, which illustrates the major units of the system, shows that the video signal starts at the camera and goes to the control unit. From the control unit the signals are sent to the monitors by way of a cable and to the receivers via air transmission.

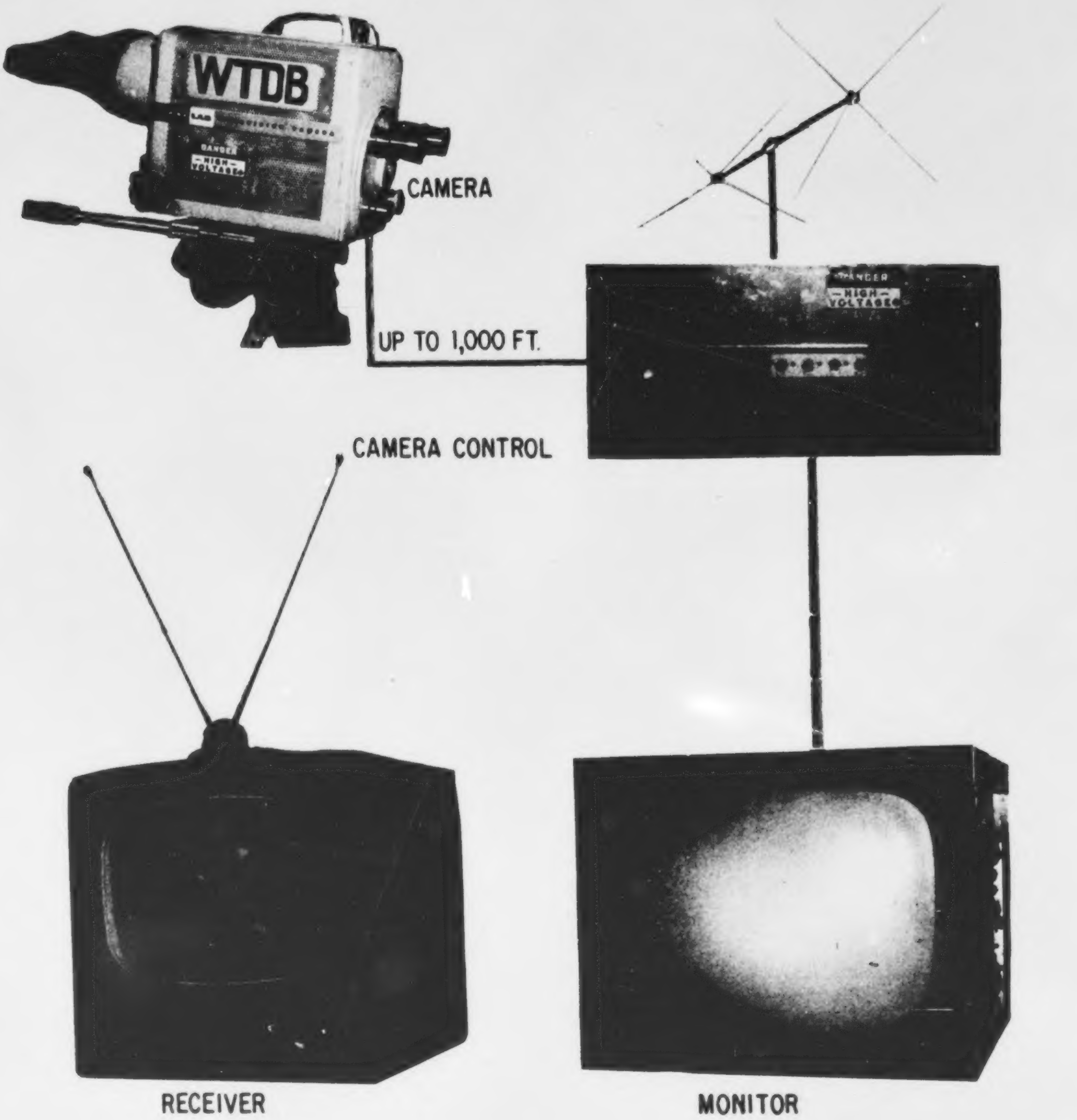


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Figure 7-41.–System components.

If one video monitor/receiver develops trouble, the first check to make is to observe the other monitors. For example, if the other monitors/receivers are working normally, it can be assumed the camera unit and control unit are functioning properly. The trouble must be either in the video monitor/receiver or in the connecting cables.

When all monitors/receivers have the same trouble, the trouble must be in some unit that is common to them. In this case, the control unit or the camera unit may be the source of trouble. Checking the input to the control unit with an oscilloscope will determine the operation of the camera unit. Correct video signals appearing at the video input jack eliminates the camera unit. This isolates the trouble to the control unit. Procedures contained in the manufacturer's maintenance manual will aid the TD in finding the faulty component.

CIRCUIT ISOLATION

Observing the picture on the receiver/monitor furnishes the TD with valuable symptoms of trouble. The sound system operation is heard through the speaker. The operating condition of practically all other circuits (fig. 7-19) is displayed on the picture tube.

Reviewing the block diagram (fig. 7-19) will show how the operation of the individual circuits is related to the other circuits. The low-voltage power supply furnishes voltages for the whole receiver. Trouble in this circuit affects both the video and sound. The received video and sound must pass through the tuner section; trouble in this circuit results in both video and sound trouble. The high-voltage supply furnishes the voltages to the picture tube for the picture raster. Trouble in this circuit would affect the brightness of the raster only, while video and sound could be normal. However, in this case, the video is present but cannot be seen because the picture tube is not illuminated.

The sweep systems are free-running and not dependent upon received signals to start their operation. When the horizontal sweep system starts oscillating, energy is supplied to the high-voltage supply circuit and the picture tube is illuminated. If the raster is present, the sweep circuits are operating. If no video (picture) is present, the trouble circuit is one that affects the picture only. Referring to figure 7-19, it can be seen that the video received at the input (antenna) passes through the tuner and then through the video section to the picture tube. If sound is heard, it can be assumed that the tuner is normal. This further isolates the trouble to the video amplifiers.

While it is beyond the scope of this training manual to describe all the possible troubles encountered, the examples in table 7-1 illustrate the technique used to isolate a trouble in a complex system to a simple circuit problem. Table 7-1 is based on a typical black and white receiver circuit using intercarrier sound with the sound takeoff circuit in the video system.

Table 7-2 deals with those problems encountered exclusively in color television receivers. Prior to troubleshooting a color receiver, you must ensure that both the black-and-white and the color portion of the receiver have been properly adjusted. The adjustment procedures for the color section include a preparatory degaussing of the shadow mask and a purity, convergence, and white adjustment. Since the installation and adjustment procedures for color television receivers differ, not only between manufacturers but also between models produced by the same manufacturer, they will not be discussed here. However, one specific rule can be given—follow the manufacturers' service notes implicitly.

APPLICATION

As stated in chapter 6, there are many uses that can be made of a CCTV system. A few of the most pertinent applicable to the Tradevman rating are discussed in the following paragraphs.

TEACHING WITH CCTV

Probably the area that makes the greatest use of CCTV is that of training. Training

Table 7-1.—Black and white TV receiver analysis

Symptom	Analysis
Receiver dead; no raster, picture or sound.	Check powerline into receiver, safety interlock switch, and powerline fuse, if any. Possible failure in low voltage supply. If tube filaments light, receiver has input power.
No sound and no picture, but raster is normal.	Power supplies and deflection circuits are operating normally to produce raster. Trouble is in the signal circuit common to both picture and sound. Check RF tuner, common IF amplifier, and sound detector. Check AGC circuit for excessive negative bias which cuts off the signal amplifiers. Check video amplifier.
Trouble on one channel, but operation is normal on other channels.	Check tuner tubes. Dirty contacts on station selector switch. Incorrect local oscillator frequency.
No brightness or raster on screen. Sound is normal.	Check high voltage circuits and horizontal deflection circuits with flyback supply; check fuse in horizontal output circuit. Picture tube cut off by excessive negative bias. Check picture tube.
Insufficient brightness.	Insufficient high voltage. Excessive negative bias on picture tube. Check low voltages. Weak picture tube. Dust on picture tube and safety glass.
Raster with picture too small, horizontally and vertically.	Low B+ supply voltage. Check line voltage and low voltage power supply.
Raster with picture too narrow, insufficient width.	Insufficient horizontal deflection amplitude. Check horizontal oscillator, amplifier, and damper circuits. Low B+ supply voltage.
Raster with picture too small vertically, insufficient height.	Insufficient vertical deflection amplitude. Check vertical oscillator and output circuits.
Raster with picture tilted with respect to mask.	Rotate deflection yoke.
Raster with picture off center, vertically or horizontally.	Check centering adjustments and tilt of focus magnet.
Trapezoidal raster and picture sides not straight (keystoning).	Defective deflection yoke.
Shadowed corner in raster and picture.	Check focusing magnet and ion trap magnet.
Picture folds over at left or right edges of raster.	Horizontal retrace time too long, or incorrect phasing of retrace with respect to blanking.
Crowding and spreading of picture at left and right sides of raster.	Nonlinear horizontal scanning. Check width, drive, and linearity controls. Weak horizontal oscillator, amplifier, or damper tube.

Table 7-1.—Black and white TV receiver analysis—Continued

Symptom	Analysis
Crowding and spreading of picture at top and bottom of raster.	Nonlinear vertical scanning. Check height and linearity controls. Weak vertical oscillator or amplifier tube.
Two narrow pictures side by side separated by black vertical bar, but of full height.	The horizontal oscillator frequency is one-half the correct frequency. Check the horizontal AFC and oscillator circuit.
Right half of picture is superimposed on left side.	The horizontal oscillator is operating at twice the correct frequency. Check oscillator circuit.
No picture, normal raster, and normal sound.	The trouble is in the circuit used only for the picture which is the video amplifier in most receivers.
Weak picture with low contrast.	Weak amplifier tubes causing insufficient gain.
Picture rolls vertically and slips horizontally.	Insufficient vertical and horizontal sync. Check common sync circuits.
Picture rolls vertically. Can be stopped but will not hold. Horizontal hold is normal.	Insufficient vertical sync. Check vertical sync circuits.
Picture slips horizontally and tears into diagonal segments. Can be stopped but does not hold. Vertical hold is normal.	Insufficient horizontal sync or trouble is in horizontal AFC circuit.
Picture (video) bends at edge, but raster is normal and straight.	AC hum in horizontal sync, or the sync is weak.
Picture not clear, insufficient detail, but focus is good. Resolution not good.	Insufficient response for high video frequencies. Bandwidth too narrow in RF and IF amplifiers. High frequencies lost in video circuits. Video detector or amplifier load resistance is too high. (See NOTE.)
No sound. Picture is normal.	Check 4.5-MHz sound IF section and audio amplifier section for bad tubes or alignment. (See NOTE.)
Distorted sound, picture normal.	Check FM detector alignment and audio section. (See NOTE.)
Hum in sound only.	The hum occurring only with picture signal present is modulation hum introduced in the 4.5-MHz sound IF section. Hum with or without signal is additive hum from the audio section. (See NOTE.)
Buzz in sound.	Check AM rejection circuit and FM detector alignment for balance. If the picture is black and out of sync, the buzz is caused by an overload condition in a common circuit for picture and sound. (See NOTE.)

NOTE: When indications and tests have localized a trouble to misalignment, the manufacturer's maintenance manual should be consulted for the proper alignment procedure. Alignment of TV circuits is a very exacting process and requires special test equipment. Attempting to align a receiver without the proper test equipment may result in more troubles than were present at the beginning.

Table 7-2.–Color Receiver Analysis

I. Defects observed in black-and-white reception.

Symptom	Analysis
Picture blurred, color fringes at the sharp outlines in the picture.	Defective convergence section. Check for proper convergence adjustment. Possible problem areas: convergence coil and magnetic assembly, blue-beam positioning magnet, deflection yoke, picture tube. If dots converge in center but either or both sides are out, a defective horizontal dynamic convergence circuit is indicated. A defective vertical dynamic convergence circuit is indicated by the failure of the dots to converge at the top or bottom. NOTE: If an abrupt shift in convergence is noted, check the high-voltage regulator.
Nonuniform coloring of the screen or colors appearing at the outer portions of the screen.	Color purity defect. Perform both purity and white adjustments. Check for weak magnets, defective picture tube, or defect in screen controls.
Nonuniform white/gray shades.	Perform white adjustments. Defect in screen controls or picture tube.
Color flashes in picture.	Defective color killer section, color phase detector, or bandpass amplifier. NOTE: There should be a large bias voltage (sufficient for cutoff) on the input to the bandpass amplifier.

II. Defects observed in color reception.

PRECHECKS:
1. Set properly adjusted to receive color, and channel selected is carrying a color program.
2. Color and hue control advanced.
3. Fine tuning control properly adjusted.

NOTE: In the absence of a color program, a color dot/bar generator will normally be required to effectively troubleshoot the color section.

Symptoms	Analysis
No color.	Defect in bandpass amplifier or color killer section. 3.58 MHz oscillator defective or widely misadjusted. Color sync section defective. Color demodulator tubes defective (only if both tubes encased in same envelope). Weak input signal due to defective antenna, tuner, or video IF stages.
Loss of color sync indicated by horizontal bands of color moving vertically across the screen.	Failure of color phase discriminator circuit. Failure in reactance tube circuit. 3.58 MHz oscillator slightly off frequency (color bands few in number). Weak signal or poor response of antenna, tuner, or picture IF stages.
Improper color rendition (four categories)	
Wrong color (transposition).	Check hue control first, then phasing circuits in color sync and demodulator sections for defects or misalignment.
Missing colors.	Check the alignment of the bandpass amplifier. See above for further checks. NOTE: If one or more electron guns are inoperative, the respective color(s) will be missing from the picture, and such a defect will show up in black-and-white reception.
Washed-out colors.	Check bandpass amplifier and its alignment. Check the color demodulator section. A weak picture tube (electron gun(s)) will produce this effect.
Color hum. (Appears as additional horizontal bars of color which are complementary to the colors of the affected channels.)	Q-channel defective–green and purple bars appear. I-channel defective–orange and cyan bars appear. NOTE: Hum originating in low-voltage power supply will appear in the black-and-white picture. See table 7-1.

depends upon effective communications. Since CCTV is a medium of communications, when properly used, it can offer many advantages in training students effectively and economically.

Television should be used as a supplement to normal classroom instructing. It cannot completely replace the instructor in the classroom. When properly used, however, CCTV can provide technical advantages for illustrating training subjects which are difficult or impossible to duplicate in the classroom. It can also be used to increase student interest, make quick and lasting impressions, and reduce the time necessary to teach a complex idea or technique. CCTV can show events or activities at the instant they occur, or it can reproduce an accurate record of them from video tape or film at any future time.

As a result of research conducted by the military and civilian agencies engaged in training by television, the following facts have been established about the effective use of television as a medium for training:

1. Students can learn from good TV presentation as well as from normal classroom instruction.

2. Slow learning students appear to learn better from TV presentations.

3. Subject matter taught by TV is usually retained as long as that taught conventionally in a normal classroom situation.

4. The TV lecture-demonstration method of teaching is simple and quite effective for instructional programs.

5. This type of training requires that the TV instructor follow proper teaching procedures, have a good knowledge of the subject being taught, and make proper use of TV techniques and equipment.

Advantages

The medium of television can offer the instructor and the student certain specific advantages. A few of the more obvious advantages are as follows:

1. It provides enrichment of training:

   a. Increases use of training aids.

   b. Increases student interest and understanding.

   c. Provides a "common grounding" of all students in certain fundamental subject areas.

   d. Gives instructors an opportunity to observe presentation techniques and methods of other instructors, and to observe students while they are watching a TV presentation.

   e. Allows the instructor more time to teach applications of complex subject matter initially presented by TV.

2. Technical advantages such as the following are provided:

   a. Gives closeup magnification of small objects, equipments, parts, meters, mechanisms, diagrams, etc., so each student has a "Front-row" seat.

   b. Changes perspective instantly from wide angle to close up.

   c. Allows comparison of two or more illustrations (equipment and diagrams, film and live view, etc.) at the same time.

   d. Directs student's attention to essential detail in an illustration, eliminating distracting surroundings.

   e. Brings "live" or recorded views of equipment and demonstrations from remote locations into the classroom.

   f. Allows use of large, small, scarce, confined, or fixed equipment regardless of its location.

   g. Allows integration of pertinent film sequences, slides, graphics, and special training aids into TV presentations specifically designed for local classroom needs.

Limitations

The medium of television has certain limitations which should be considered in determining its usefulness for a training program. A few of the more obvious limitations are as follows:

1. TV is generally a one-way communication system. It is not used to replace the classroom instructor, who is needed to clarify any questions of the students (CCTV is designed to supplement the instructor's efforts so that he can teach more effectively and efficiently).

2. TV teaching is expensive. The cost is offset, however, when a program can reach a number of students at one time or sequentially over a period of time, or when TV provides significant information not otherwise available in the classroom.

3. TV subjects are not taught in the same manner in which they would be taught in a classroom. TV can use special techniques of presentation, but often requires rearrangement of subject sequence. Classroom instructors must adapt TV presentations to their own class needs.

4. TV cannot cover every subject desired. Time and economical use will not allow the presentation of every complex or specialized subject by TV. Over a period of time, however, a library of useful TV presentations can be established.

5. TV serves as a medium of communication, and is only as effective as the original effort expended in preparing the subject for presentation.

Facilities and Capabilities

The actual use made of a CCTV system depends largely upon the facilities and capabilities of the equipment available. These will also determine the size of the crew and how a studio is used.

For example, a rather simple CCTV system is employed by the Instructor Training (IT) School in Memphis, Tenn. (fig. 7-42). The system is composed of a black and white Ampex camera, a Sony video tape recorder (VTR), and a monitor. It is utilized in the following manner. After an equipment checkout by TD maintenance personnel, the system is turned over to the instructor-trainees. They, in turn, video tape each other's presentations (lessons), play the lessons back on the monitor, and self-criticize or critique the presentations they have just made.

CCTV USED WITH FLIGHT TRAINERS

Takeoff and landing of high performance aircraft are the most critical phases of an aircraft's journey. The pilot must gather many bits of information such as altitude, speed, wind direction, and position. During landing operations, he must also know the shape of the runway and its relationship to the horizon during the approach. Because the pilot's information concerning the moment-to-moment potentialities of success during these maneuvers arrives from many different sources, the problem of information assimilation is crucial. In the past the only solution to this problem was extended practice of takeoffs and landings with the actual aircraft.

The operational flight trainer and the instrument flight trainer allowed the pilot to practice cockpit operations, but did not provide visual acquisition of his surroundings. The addition of CCTV systems to trainers such as the 2F23, 2F25, and 2F58 provides the following advantages:

1. Pilots can practice landings and takeoffs without leaving the ground.

2. Procedures for GCA and ILS training can be conducted to final touchdown.

The Low-Visibility Approach and Landing Attachment for Flight Trainers, Device 2H53 (fig. 7-43), is designed to be attached to instrument flight trainers, operational flight trainers, and weapon system trainers. It provides a visual presentation of a full color display of a runway or carrier deck equipped with

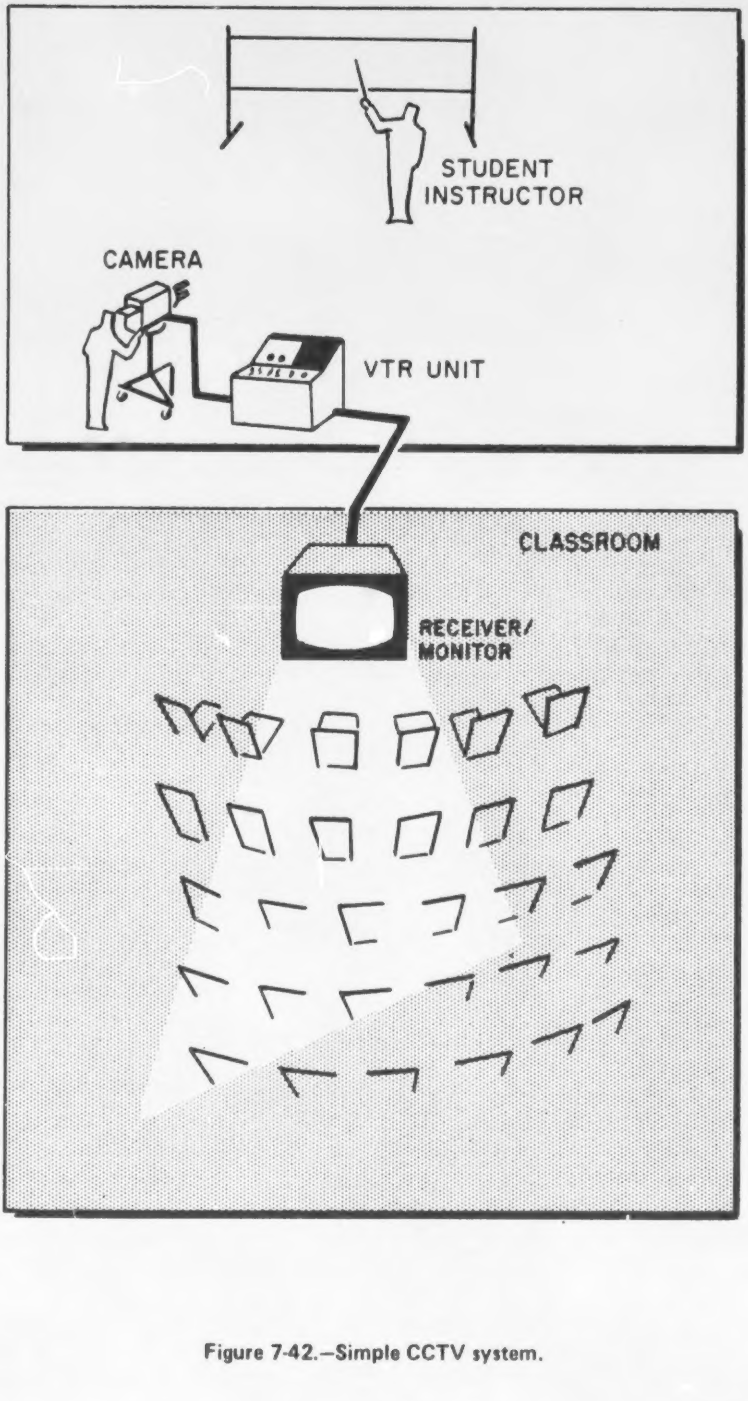

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Figure 7-42.—Simple CCTV system.

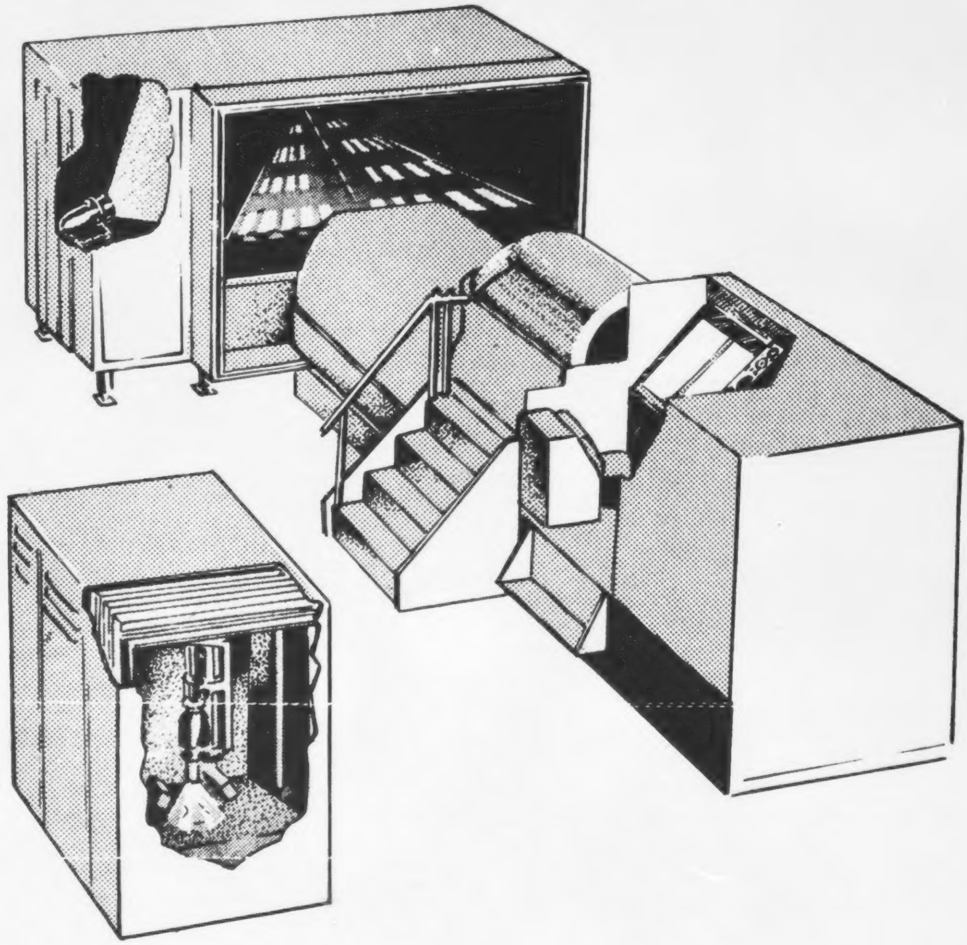

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Figure 7-43.–CCTV attachment for trainers, device 2H53.

appropriate markings and lights. This device aids pilots in acquiring proficiency in the art of landing under low visibility approach conditions. It also simulates the landing lights and Fresnel Lens System on a carrier. Ceiling and visibility (in approach cone) can be varied from 0-0 to 1,000 feet at 3 miles in a light haze under night conditions only.

The device enables the flight trainer pilot to simulate either takeoff from a carrier deck and landing at a land base, or takeoff and return from either base.

CHAPTER 8

INTRODUCTION TO DIGITAL SIMULATOR SYSTEMS

The information presented in this and the following chapter is based on the premise that the student has completed the NRCC written for the training manual *Digital Computer Basics*, NAVEDTRA 10088-A. Without this background information, it will be, at best, difficult to understand the following discussion.

These chapters constitute an introduction to the operation and maintenance of typical digital simulator systems. Basic Instrument Flight Trainer, Device 2B21, is used as the primary training vehicle to accomplish this task. However, it would be presumptuous to think that the information presented in this chapter constitutes a course on the 2B21. In fact, most of the circuits presented in this chapter have been simplified and/or generalized with the intent of presenting a concept, not a specific piece of equipment. For example, the timing pulse generator for the interface unit has been redrawn and simplified using JK flip/flops. As with any training device, questions concerning the actual circuits used in the device should be resolved by referring to the maintenance handbooks. Where appropriate, comparisons and contrasts will be drawn with other trainers to show variations in simulation methodology.

SYSTEM OVERVIEW

Most digital simulator systems can be functionally block diagramed as shown in figure 8-1. They will contain (1) one or more digital computers, (2) a relatively large interface system, and (3) a training vehicle, composed of an instructor/operator console and a student station. Digital simulators take this form due, in part, to the nature of the computations involved in the problem solutions. Within the digital computer, numerical equivalents are used to represent both the data to be processed and the instructions for processing the data. Since digital computers operate on discrete data, incoming data must be presented to the Central Processing Unit (CPU) in the proper form and at the proper time. These two requirements dictate the need for an interface (with components such as I/O buffers, control and decoding circuits, and converters (A/D, D/A, and D/S)). This permits the trainee/operator stations to communicate with the computer, and vice versa.

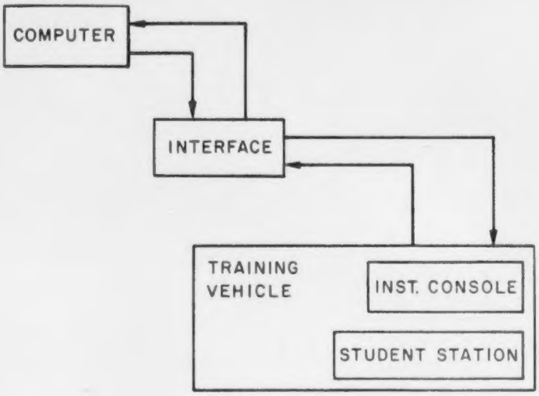

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Figure 8-1.—Digital simulator system.

DIGITAL COMPUTERS

Through its program, the digital computer is the heart of the digital simulator. The program employed in each different simulation is based on algorithms of that simulation. An algorithm is nothing more than a procedure for accomplishing some particular task involving calculations. For example, the algorithms used to describe aircraft flight include equations for lift, drag, thrust, etc. These equations are repetitiously solved by the computer program. The operation of simulator programs is discussed in more detail later in this chapter.

Appendix 1 lists most of the general purpose digital computers incorporated into Cog "20" training equipment. As noticeable from this appendix, there is a wide variety of device types, manufacturers, and computer models represented in the digital simulation field.

Each model or series of computer has its own machine language. Even though the languages are unique, the functions these instructions perform are common to all. For example, all computers have a repertoire of instructions that (1) provide for the TRANSFER of information, (2) perform ARITHMETIC and LOGIC functions, and (3) perform [illegible] CONTROL function. A brief introduction to four representative computers and their respective word formats follows.

DDP-124

One of the largest manufacturers of computers employed in digital simulators is the Honeywell Corporation. Their "DDP" series of machines includes a wide variety of both second and third generation computers. The DDP-124 is a compact, general purpose computer that utilizes monolithic integrated circuits (circuits in which the elements are formed upon or within a semiconductor substrate). The computer features 24-bit words with a 1.75 μsec memory cycle time. Standard features include: 48 single-address instructions, sign-magnitude representation of numeric operand words, indexing and indirect addressing, 8,192 directly addressable words of core memory, and peripheral equipment that includes a typewriter, paper tape reader, and punch.

Refer to figure 8-2 for the instruction/data word format used by the DDP-124. Note that both instruction and single-precision operand words are 24-bits in length. Double-precision operands are two 24-bit words; the signs of both words must be alike.

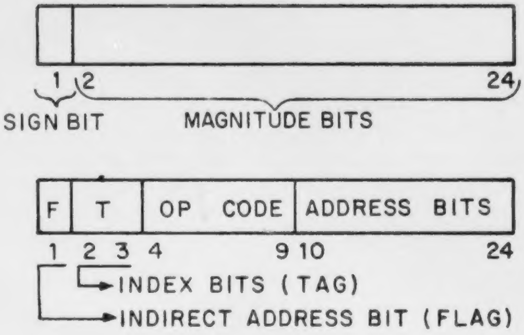

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Figure 8-2.—Word formats DDP-124.

Numeric Operand Words

Single precision, fixed point numbers are represented in true sign-magnitude form. Bit position 1 is the sign bit; a ONE indicates a negative number and a ZERO indicates a positive number. The remaining 23 bits of the word represent (in true binary form) a magnitude of $\pm 2^{23}$, or $\pm 8{,}388{,}608_{10}$.

Instruction Words

In addition to the OP-code (bits 4-9) and address field (bits 10-24), there are three address modification bits. Bit position 1, called the "flag", indicates whether or not the indirect address mode will be used; bit positions 2 and 3, called the "tag", indicate which index register, if any, will be used in the operation.

DDP-516

If quantity were used as the only criterion, the most popular digital computer model employed in training devices is the Honeywell DDP-516. There are approximately 84 of these machines used in 11 different types of devices. The DDP-516 is an integrated circuit, 16-bit binary word, general purpose digital computer with a memory cycle time of .96 μsec. This medium-size computer uses parallel machine organization and both indexing and multilevel indirect addressing. Even though this older machine (1960s) preceded the minicomputers by a few years, it employs features found in many of the latest minis. Two examples of these features are the 16 bit word length and the use of paging (sectors) to address memory.

Word Formats

Refer to figure 8-3 for the data/instruction formats used by the DDP-516. Both single and double precision data words are available. The sign position of the second (least significant) word is always zero; hence, thirty bits of magnitude are obtainable. Instruction words are divided into four different types: memory

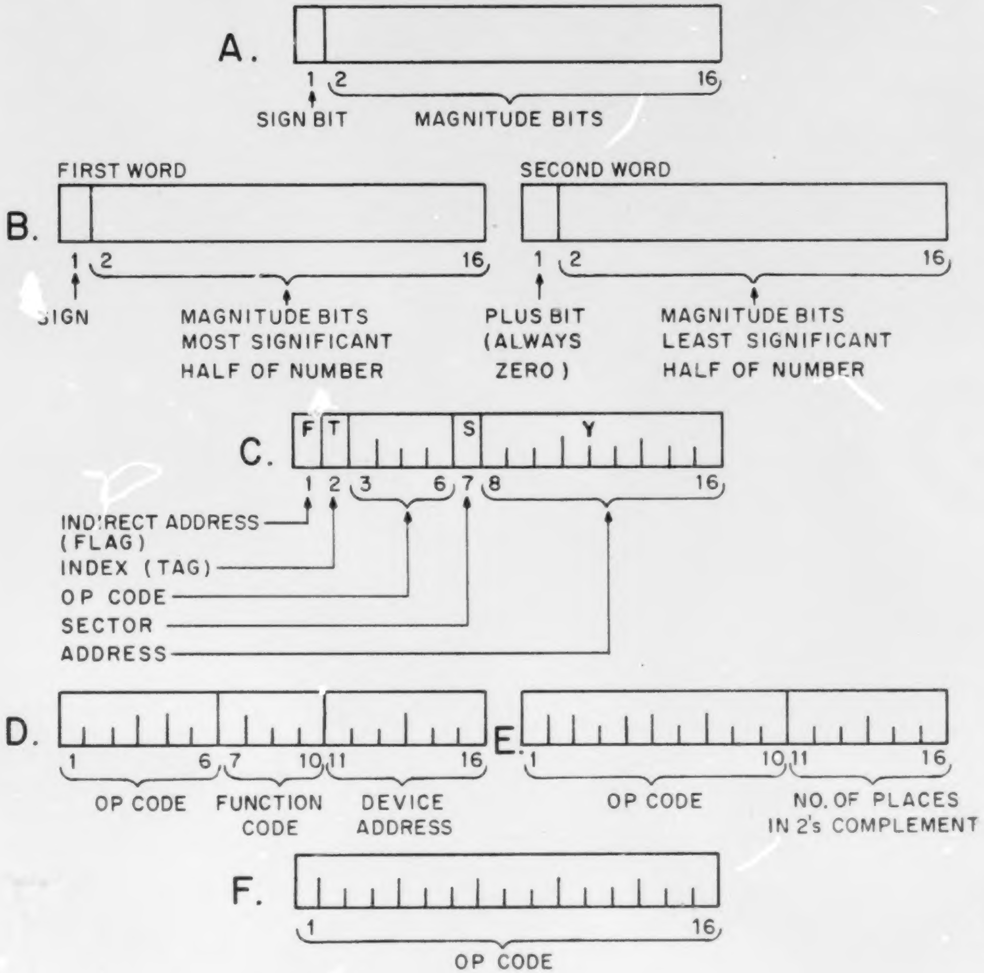

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Figure 8-3.—Word formats DDP-516.

reference, input-output, shift, and generic (entire word length devoted to OP code).

The memory reference instruction format is shown in figure 8-3(C). Bits 1 and 2 are the Flag and Tag bits and are used in the same manner as in the DDP-124. Bits 3 through 6 are reserved for the operation code, while bit 7 is the sector bit. Sector addressing (paging) is explained in detail in the next section on minicomputers. Bits 8 through 16 are used for the address.

The input/output instruction word format is shown in figure 8-3(D). Bits 1 through 6 specify the particular I/O instruction to be performed. Bits 11 through 16 specify which device is being addressed, while bits 7 through 10 define the function to be executed by the instruction.

The shift instruction word format is shown in figure 8-3(E). Bits 1 through 10 specify the type of shift, and bits 11 through 16 are used to define the number of shifts to be performed. The number of shifts must be presented in two's complement form.

The generic instruction word format is shown in figure 8-3(F). All 16 bits are used to specify the operation code.

MINICOMPUTERS

Low prices and the ready accessibility of integrated circuits and inexpensive memories have led to the development of a group of small general-purpose digital computers usually called "minicomputers." Minicomputers are defined as those machines which, with minimum memory and limited I/O devices, cost under $10,000. Because of this low cost, the trend of manufacturers of training devices is to employ these "minis" in the newer simulators.

Since the manufacturer of the "mini" is tasked with keeping expenses down, several new design features are incorporated into these machines that are not found in the older computers. One of the most obvious differences is the shorter word lengths of the "minis", usually from 8 to 16 bits. This limits the length of both the OP-code section and the memory address section of the instruction word. A limited OP-code section limits the number of different instructions, while the limited memory address section demands some method be devised to address the entire memory.

The minicomputer engineer circumvents the first problem, a small instruction set, by including several ingenious instructions with the conventional set. For example, a "complement and add one" instruction is used with an "add" instruction to produce a programmed "subtract" instruction. Multiple operation instructions are also employed. For example, a single instruction may add, rotate, test, and skip.

To overcome the second problem, that of addressing a large memory with a short word, a number of different memory addressing techniques have evolved. One of the more popular methods employed is "paging". When "paging" is employed, the memory is divided into pages, each of a fixed length. As an example of this paging technique, consider a minicomputer with a basic core memory of 4,096 words of 16 bits each. This memory could be divided into 32 pages of 128 words each. See figure 8-4. Page 0 contains memory locations zero to 127_{10}, page 1 contains locations 128_{10} to 255_{10}, and the last page, 32, contains locations 3967_{10} to 4095_{10}. Then 5 bits are required to reference a page, i.e., $2^5 = 32$ different binary numbers; 7 bits are needed to reference the locations on a page, i.e., $2^7 = 128$ different binary numbers.

Addressing memory in a computer that utilizes paging varies from computer to computer. Most often the address given in an instruction word refers to either the page in which the instruction word lies or to some other particular page previously specified. One of the medium size computers, the DDP-516, uses a particular bit, bit 7, in a 16 bit instruction word to indicate to the computer whether the address refers to page "0" or to the page in which the instruction lies. Note: The "pages" are called "sectors" in the Honeywell computers.

Direct, indirect, relative, and index addressing are also used singularly or in various combinations to overcome this addressing problem.

NOVA 800

The Nova line of general purpose minicomputers, built by Data General Corp., is a series of two-address, 16-bit word, third generation machines. All arithmetic and logic

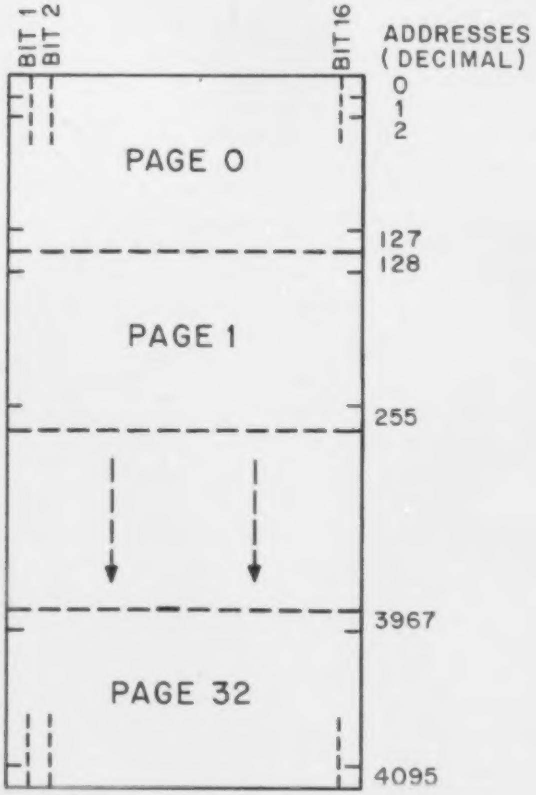

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Figure 8-4.—Paging.

operations are performed between accumulators. The various Nova machines differ from one another in particular features and speed, but more importantly to the TD, use the same instruction set.

The Nova 800, nine of which are utilized in Training Device 1D23, has a core memory with a cycle time of 800 nanoseconds and a capacity of 32,000 words. Each instruction word, addressing a memory location, contains information for determining the effective address, which is the actual address used to fetch or store the operand or alter program flow. Memory locations are addressed by a displacement and an index. The displacement can be an absolute address or it may be used as a signed number that is used to compute an absolute address by adding it to a 15-bit base address supplied by an index register. Indirect and relative addressing are also employed. Automatic incrementing and decrementing is another powerful feature of the machine.

Instruction Formats

There are four basic formats for the instruction words (see fig. 8-5). the first three bit positions are used as a code to determine which address format is to be implemented. In all but the arithmetic and logical instructions, bit 0 is 0. If bits 1 and 2 are also 0, bits 3 and 4 specify the function (JUMP or MODIFY MEMORY) (fig. 8-5B) and the rest of the word supplies information for calculating the effective address. Bits 8-15 are the displacement, bits 6 and 7 specify the index register, if any, and bit 5 indicates the type of addressing, direct or indirect.

If bits 1 and 2 differ, they specify a MOVE DATA function (fig. 8-5C). Bits 3 and 4 address an accumulator; the rest of the word is the same as above.

The third format used is the IN-OUT instruction format (fig. 8-5D). Bits 1 and 2 both being 1 identify this format as an I/O instruction. In this case the function is specified by bits 5-9, of which bits 5-7 indicate the direction of transfer and select one of three registers in the device. Bits 8 and 9 of the function part specify an action to be performed, such as starting the device. The transfer takes place between the accumulator addressed by bits 3 and 4 and the device selected by bits 10-15. If bits 5-7 are all 0 or all 1, there is no transfer, and bits 8 and 9 specify a control or skip function, respectively.

The fourth and final instruction word format is that used by the ARITHMETIC and LOGIC functions (fig. 8-5E). If bit 0 is 1, bits 5-7 specify an arithmetic or logic function. One operand is taken from the accumulator addressed by bits 1 and 2; a second operand, if any, from that addressed by bits 3 and 4. The balance of the bits specify options for additional operations after the basic arithmetic operation is

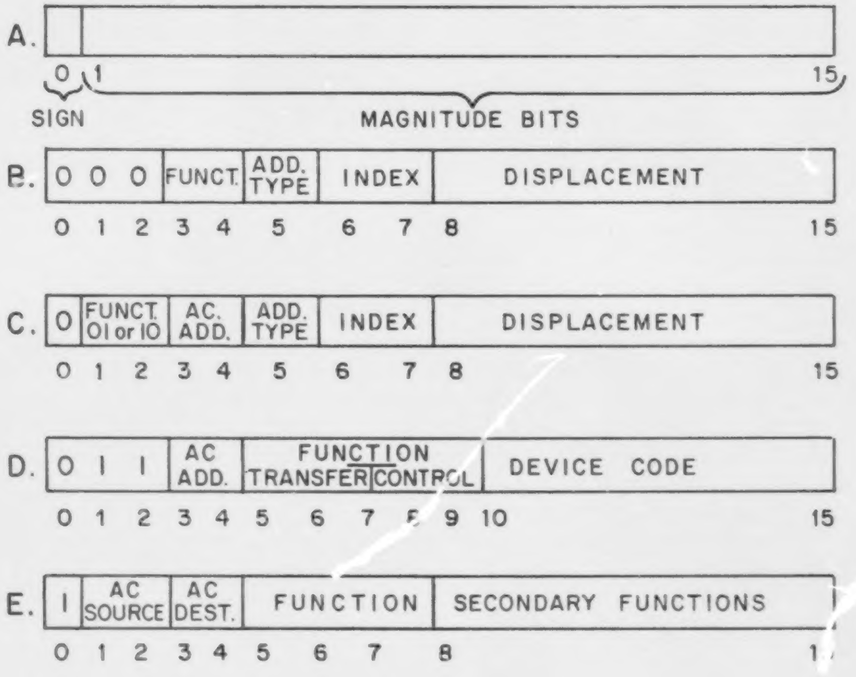

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Figure 8-5.—Word formats NOVA 800.

performed. For example, the result may be shifted or not used, or the instruction can select from several options for skipping based on an arithmetic result that is positive, negative, zero, overflows, etc. Several minicomputer manufacturers use this ability to combine several operations to be performed in order in a single instruction.

PDP-11/45

One of the latest and more powerful minicomputer families is the Digital Equipment Corporation PDP-11 series. As in the NOVA line, this series of computers is upward compatible, i.e., the PDP-11/15, used in the 2F78, employs the same basic instruction set as in the PDP-11/45. These third generation computers utilize a 16-bit word, employ either solid state or core memories, and have many features not normally associated with the smaller computers.

The PDP-11/45 computers, utilized in Device 2F101 and others, have 16 general purpose registers, a multiply and divide instruction, and a multiline, multilevel system of automatic priority interrupts. There are also 8 levels of software interrupts available. The CPU has a cycle time of 300 nanoseconds and performs all arithmetic and logic operations.

Much of the power of the PDP-11 is derived from its wide range of addressing capabilities. The addressing modes include sequential addressing, full address indexing, full 16-bit word addressing, 8-bit byte addressing, and stack addressing. A stack is a temporary data storage area which allows a program to make efficient use of frequently accessed data. The stack is used automatically by program interrupts, subroutine calls, and trap instructions.

Instruction Formats

The instruction formats for the PDP-11/45 computer are shown in figure 8-6. Note that both single and double operand instruction formats are used. In the single operand format (fig. 8-6(A)), used by instructions such as the rotates, clears, and shifts, bits 15-6 specify the operation code, and bits 5-0 form a six-bit field called the destination address field (dst). The dst is divided into two subfields; bits 0 through 2 specify which of 8 general purpose registers is to be referenced by the instruction word, and bits 3 through 5 specify what addressing mode will be used. Contained within the mode field is a direct/indirect addressing bit, bit 3, and the mode identification bits, bits 4 and 5.

Operations which imply two operands (such as add, subtract, move, and compare) are handled by instructions that specify two addresses (fig. 8-6(B)). The first operand is called the source operand (Src), the second the destination operand. Bit assignments in the source and destination address fields may specify different modes and different registers.

Addressing

There are four basic modes used with both the direct and indirect addressing. These modes include REGISTER, AUTOINCREMENT, AUTODECREMENT, and INDEX. When they are used with indirect addressing, Digital Equipment Corp. has named them REGISTER DEFERRED, AUTOINCREMENT DEFERRED, etc. Since each deferred mode is similar to its basic mode counterpart, separate explanations will not be given.

REGISTER MODE.—With the register mode, any of the general registers may be used as simple accumulators, and the operand is contained in the selected register.

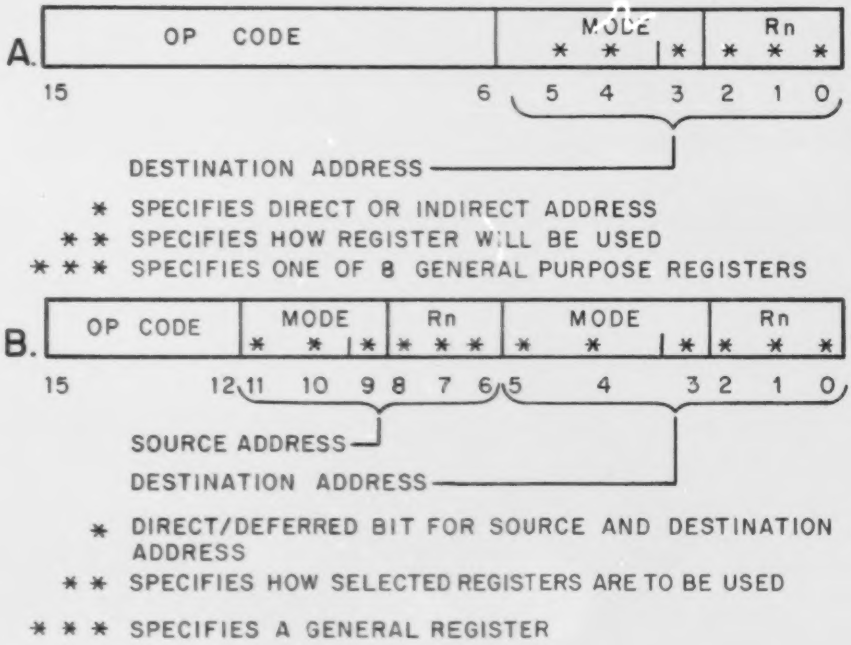
A.
OP CODE
MODE
Rn
* * | * * * *
15
6
5 4 3 2 1 0
DESTINATION ADDRESS
* SPECIFIES DIRECT OR INDIRECT ADDRESS
* * SPECIFIES HOW REGISTER WILL BE USED
* * * SPECIFIES ONE OF 8 GENERAL PURPOSE REGISTERS
B.
OP CODE
MODE
Rn
MODE
Rn
* * | * * * * * * | * * * *
15
12 11 10 9 8 7 6 5 4 3 2 1 0
SOURCE ADDRESS
DESTINATION ADDRESS
* DIRECT/DEFERRED BIT FOR SOURCE AND DESTINATION ADDRESS
* * SPECIFIES HOW SELECTED REGISTERS ARE TO BE USED
* * * SPECIFIES A GENERAL REGISTER

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Figure 8-6.—Word formats PDP 11-45.

AUTOINCREMENT MODE.–With this mode the register provides the address of the operand. Upon completion of the execution of the instruction, the contents of the register is incremented by–1 for "byte" instructions and 2 for "word" instructions. This method of addressing is used very effectively for automatically stepping a pointer through sequential elements of a table of operands.

AUTODECREMENT MODE.–In this mode, the contents of the selected register are decremented by–2 for "word" instructions and 1 for "byte" instructions–and then used as the address of the operand. The choice of postincrement/predecrement features for the PDP-11 were not arbitrary decisions, but were intended to facilitate hardware/software stack operations.

INDEX MODE.–This method of addressing is slightly different from that found in most computers in that the "INDEX" is a word in memory vice the contents of an "INDEX REGISTER". The contents of the selected register, and an index word following the instruction word, are summed to form the address of the operand.

(NOTE: In the autodecrement deferred (indirect) addressing mode the register is always decremented by 2, even for byte instructions.)

PROGRAM COUNTER USED AS GENERAL REGISTER.–Although Register 7 is a general purpose register, it doubles in function as the Program Counter (PC) for the PDP-11. The PC responds to all the standard addressing modes. However, when referring to the PC, these modes are termed immediate, absolute, relative, and relative deferred, as summarized below:

Immediate: Operand follows instruction.

Absolute: Absolute address follows instruction.

Relative: Address of A, relative to the instruction follows the instruction.

Relative Deferred: Address of location containing address of A, relative to the instruction, follows the instruction.

When a standard program is available for different users, it is often helpful to be able to load it into different areas of core and run it there. The PDP-11s can accomplish the relocation of a program very efficiently through the use of position independent code (PIC) which is written by using the PC addressing modes.

SUMMARY

As can be seen from the above discussion, the thrust of development of computers that have been and will be used in training devices is towards the small minicomputer. This trend has been from the old larger systems, through the medium size (DDP-516), to the latest minis incorporated in training devices, the PDP-11 series. The DDP-516 and the PDP-11 computers constitute over half the number of third generation machines found in training devices.

What effect will the use of the minis have on the TD instructor/maintenance man? Very little once you become familiar with (1) the basics of digital computers, (2) the special techniques of addressing mini memories, and (3) the complex repertoire of instructions used by the minis.

INTERFACE

An interface is nothing more than a shared boundary. When used in reference to digital simulators, it is the boundary between the digital computer and the training vehicle. The construction of each interface utilized in the mating of computer to training vehicle is unique for each different type of device. However, there are similarities between all interface systems in that they will, at most, process four different types of signal transfers–analog inputs, discrete (digital) inputs, analog outputs and discrete outputs. Processing these signals requires an interface that utilizes I/O buffers, employs a cyclic timing and control (decoding) section, and contains data converters.

Figure 8-7 is a simplified block diagram of the interface system used in Device 2B21. Note that each of the basic components is represented: (1) I/O buffer, (2) Timing and control unit, with a real time clock (RTC), (3)

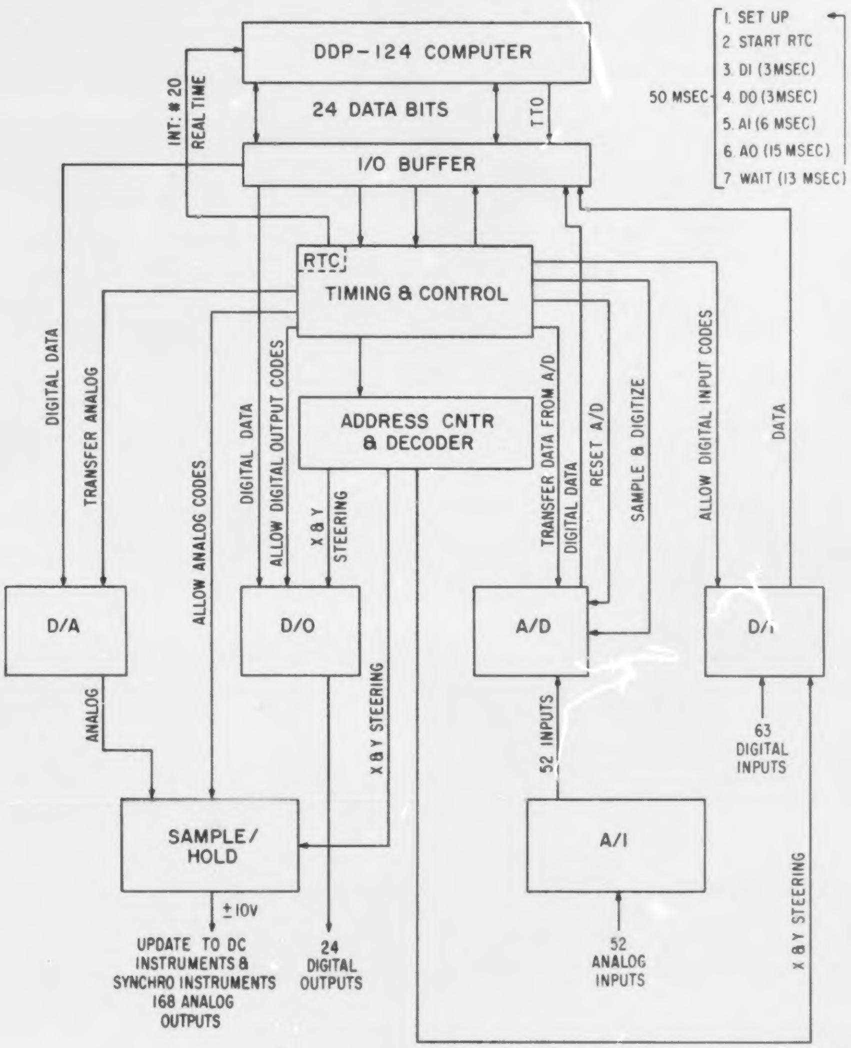

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Figure 8-7.—Device 2B21 interface.

Address counter and decoder, and (4) data converters. These functional components are discussed below.

I/O BUFFERS

I/O buffers are simply temporary storage devices (registers) used to compensate for differences in the rate of flow of data and/or time of occurrence of events when transferring data from one device to another. Typically, a high speed computer will transfer data (usually in parallel) into the buffer at a nano- or micro-second rate. Then, under control of the timing and control section, the data will be transferred to the converters at a rate that is not necessarily the same as the computer transfer rate.

Buffer capacity is normally dictated by the length of the computer word. This is the case in Device 2B21 where the I/O buffer and computer word (DDP-124) are both 24 bits in length.

TIMING AND CONTROL

Timing and control circuits generate the necessary clock and control signals required to coordinate the two-way flow of information from the computer, through the I/O buffer, through the proper converter (if necessary), to the instructor/trainee stations, and back to the computer. These signals are generated in both the computer and the timing and control section of the interface unit.

Computer Control Signals

All digital computers used in training devices have a series of instructions controlling external data flow to and from the computer. These instructions generate signals that control the I/O buffer (clear, enable, set, etc.) and other devices found in the interface unit (A/D and D/A converters, etc).

The DDP-124 instruction, OUTPUT CONTROL PULSE (OCP), is an example of an instruction that generates a computer control signal. This OCP pulse is then used (by the interface) to generate other device control signals. When used to communicate with or control the Device 2B21 interface, the OCP command takes the form OCP400XX. The XX is a code used to indicate ANALOG OUTPUT (04), ANALOG INPUT (20), DIGITAL INPUT (40), and DIGITAL OUTPUT (10).

Figure 8-8 is a simplified diagram of the CONTROL-SIGNAL generation used by Device 2B21. The OCP signal (a digital pulse) is received at gate A where it is inverted and sent to gate B. The second NAND gate inverts the pulse again and sends it to emitter follower C. The emitter follower serves as a buffer for the computer-generated OCP signal and as a driver for gates D through J. Also at the input to these gates are the "Enable I/O channel" signal (generated within the computer control circuitry) and a decoded signal, XXD or XX$\overline{D}$, derived from the particular OCP command that has been given. For example, if the computer program wants to do ANALOG INPUTS, gate D will be enabled by the following signals: 10D, 20$\overline{D}$, OCP, and ENABLE I/O CHANNEL. This pulse will be transmitted through OR gate K, setting flip-flop Q. Flip-flop Q will then output a pulse through emitter follower U that indicates INPUTS are being executed. The balance of the signals are generated in a similar manner and are distributed as inputs to gates in the timing control shift register and the device control section.

Interface Timing

Shift registers, ring counters, or binary counters are the devices usually used to generate the timing pulse chains that are required to ensure the proper timing of events in an interface system. In Device 2B21 these timing pulses are generated by a six-stage right-shift register. A simplified representation of this timing pulse generator is shown in figure 8-9. The register is preset to various configurations dependent upon the computer control signals just described. These control signals are shown as inputs to gates 1 and 2.

Operation of the shift register is identical for each timing pulse chain (analog-in, analog-out, digital-out, and digital-in), therefore only the analog-out timing is described.

(1) The shift register is initially placed in the reset condition (a system clear pulse goes through amplifier gate 3 to dc reset each flip-flop).

(2) OR gate 1 is enabled by the ENABLE I/O CHAN. signal. The output of OR gate 1 sets flip-flops C through F.

(3) The inputs to gate 2 are also true, setting flip-flop A. Note that the ANALOG signal is also fed to the dc set of flip-flop B, setting it. Thus, for ANALOG-OUT, all six flip-flops start out in the set condition.

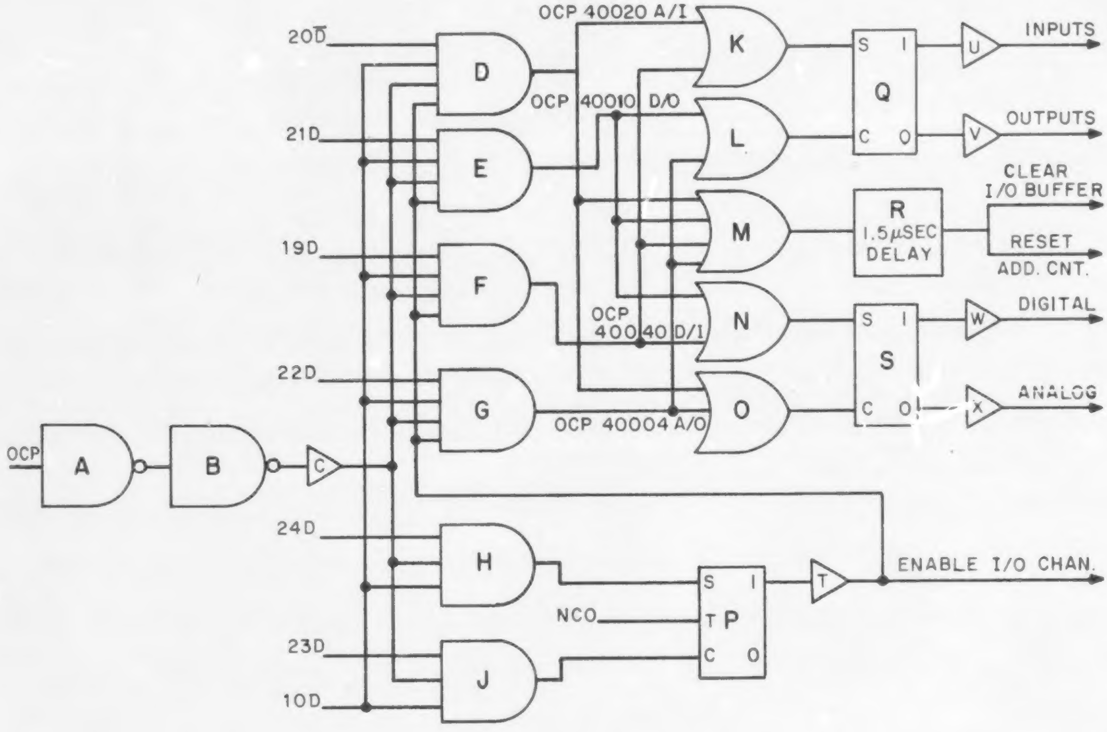

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Figure 8-8.—Computer generated control signals.

(4) When flip-flop F goes set, as it will for each of the four cases, the logic 1 is gated through gate 6 (delay circuit H is outputting a logic 0).

(5) The output of gate 6 (a positive going pulse) is inverted by the NOR gate and fed to the delay circuit as a negative going pulse.

(6) This transition to zero triggers delay circuit G which, in turn, outputs a 7-microsecond positive pulse. At the end of the 7-microsecond delay, when the pulse transitions to zero, it triggers the second delay circuit H.

(7) The output from H is another 7-microsecond positive pulse. When this pulse goes positive the output of gate 6 goes to zero (inhibiter on gate 6). This negative going pulse (from gate 6) is fed to gate 4, amplified, and sent to each of the flip-flops as the first shift pulse. Thereafter the shift pulses occur at a 14-microsecond rate (delay of G plus the delay of H).

The timing for ANALOG-OUT is Cl 1 true for 7 microseconds, Cl 2 true for 21 microseconds, Cl 3 true for 35 microseconds, etc. Note that the only difference between this mode and the other three is the initial preset condition of the flip-flops.

Device Control

The device control section of the interface system (see fig. 8-10) generates the control signals for the A/D converter, the D/A converter, digital inputs, and digital outputs.

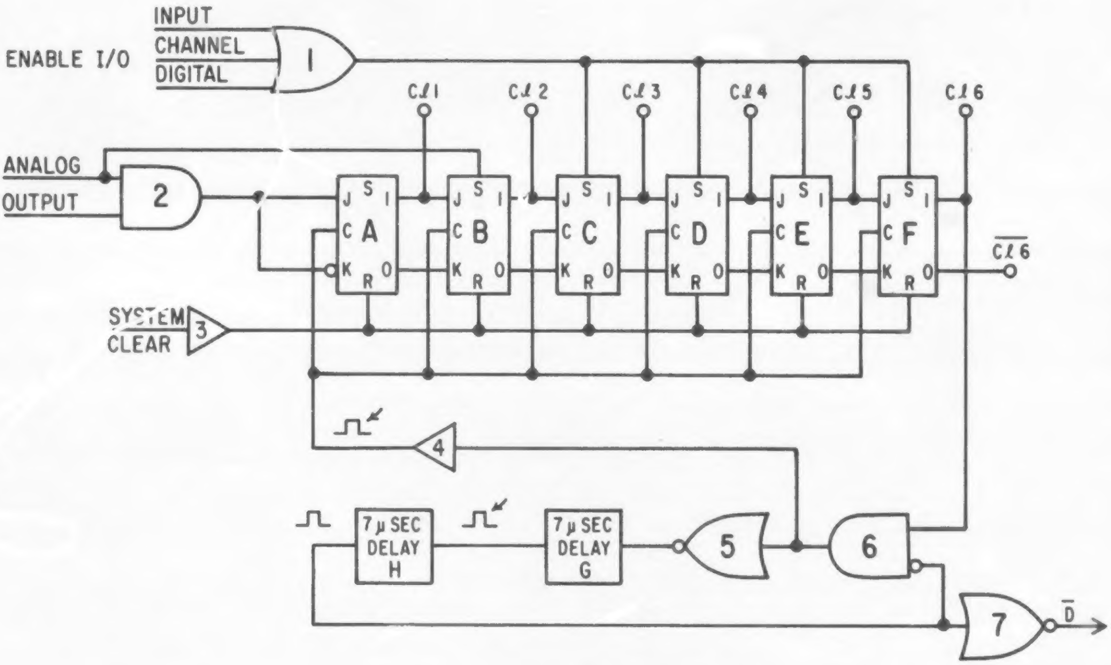

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Figure 8-9.–Timing pulse generator.

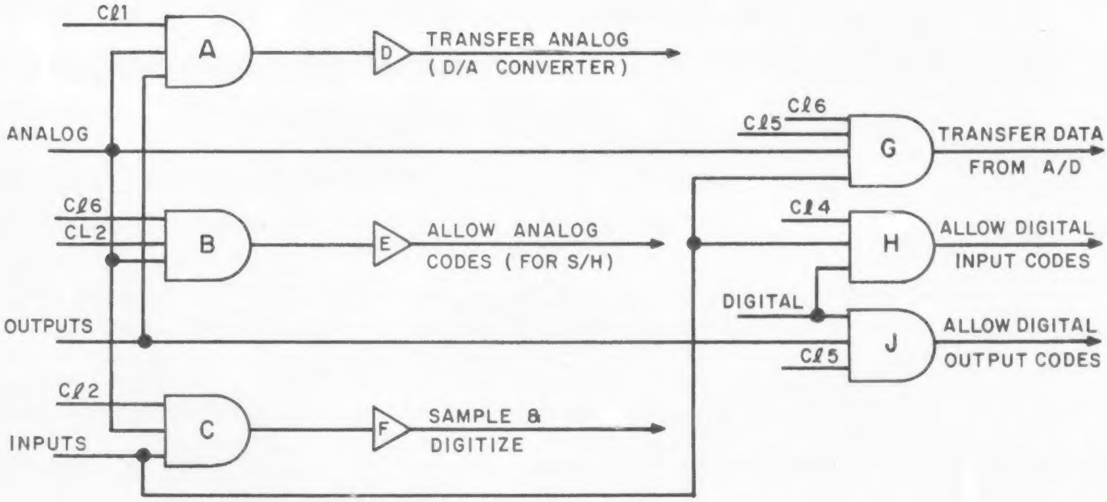

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Figure 8-10.–Device control signals.

These control signals are generated by ANDing the signals generated by flip-flops Q and S (figure 8-8) with the clock pulses (Cl) figure 8-9.

As seen in figure 8-10, the logic for these operations is rather simple and straightforward. For example, to generate the signal "ALLOW DIGITAL INPUT CODES", signals Cl 4, INPUTS, and DIGITAL are ANDed by gate H. The output from gate H is then sent to the digital input decoding section; D/I in figure 8-7. The other device control signals are generated in a similar manner.

ADDRESS COUNTER AND SEXADECIMAL DECODER

The address counter and sexadecimal decoder provide the X and Y steering signals for the digital input decoding, digital output decoding, analog output decoding, and direct synchro drive sample and hold (fig. 8-7). By using different "allow codes" (fig. 8-10), the same X and Y steering signals will be used to sequentially address all of the I/O devices except A/I. A further benefit of this type of implementation is that a single D/A converter can be used to convert 168 different analog outputs.

The address counter is an eight stage binary up counter and is reset by the pulse $\overline{\text{RESET ADDRESS COUNTER}}$ (fig. 8-8). The inputs are $\overline{D}$ and $\overline{\text{Cl 6}}$ (fig. 8-9); and it counts these successive input pulses and outputs the appropriate count as 2^0 through 2^7. Operation of the counter is not discussed here since counters are described in Chapter 4, *Digital Computer Basics*, NAVTRA 10088-A.

The sexadecimal decoder consists of gates, level changers, and emitter followers that accept counter inputs of 2^0 and $\overline{2^0}$ through 2^3 and $\overline{2^3}$, and outputs steering signals X0 through X15. Also, the counter outputs of 2^4 and $\overline{2^4}$ through 2^7 and $\overline{2^7}$ are decoded into the Y steering signals of Y0, Y16, Y32, ..., Y160.

CONVERTERS

All digitally stimulated training devices that employ voltage/current driven output devices require digital to analog and analog to digital converters. Another name for these converters is translators. They translate the language of the digital device (discrete 1's and 0's) into the language of analog devices (voltages/currents), and vice versa.

Analog to Digital Converters

Device 2B21 utilizes a multichannel A/D converter to transform the analog signals generated in the instructor/trainee stations to a 10-bit (plus sign) digital data word that is sent to the I/O Buffer register. Figure 8-11 is a simplified block diagram of this converter. It operates as follows:

(1) Each unknown analog voltage input is applied to one of 52 analog switches.

(2) A Sample and Digitize control signal is used to control the scan step signal. The scan step signal causes the scanner to close the analog switches sequentially, allowing the different scanned analog voltages to be fed to the comparator.

(3) The comparator compares the scanned voltage with a test voltage generated in the D/A converter.

(4) The digital value in the AD register is systematically changed (under control of the Bit Sequence and Comparator signals) until the test voltage is equal to the scanned voltage. i.e., when the comparator outputs zero voltage.

(5) When the comparator outputs zero voltage, the digital data contained in the AD register is a correct representation of the scanned analog voltage.

(6) These 11 bits of digital information are sent through the I/O Buffer under control of the Transfer Data From A/D signal, to memory.

Digital to Analog Converters

The D/A converter used in Device 2B21, figure 8-12, is a single channel, bipolar binary D/A converter consisting of:

(1) An input data register

(2) A precision 12-bit binary ladder adder network

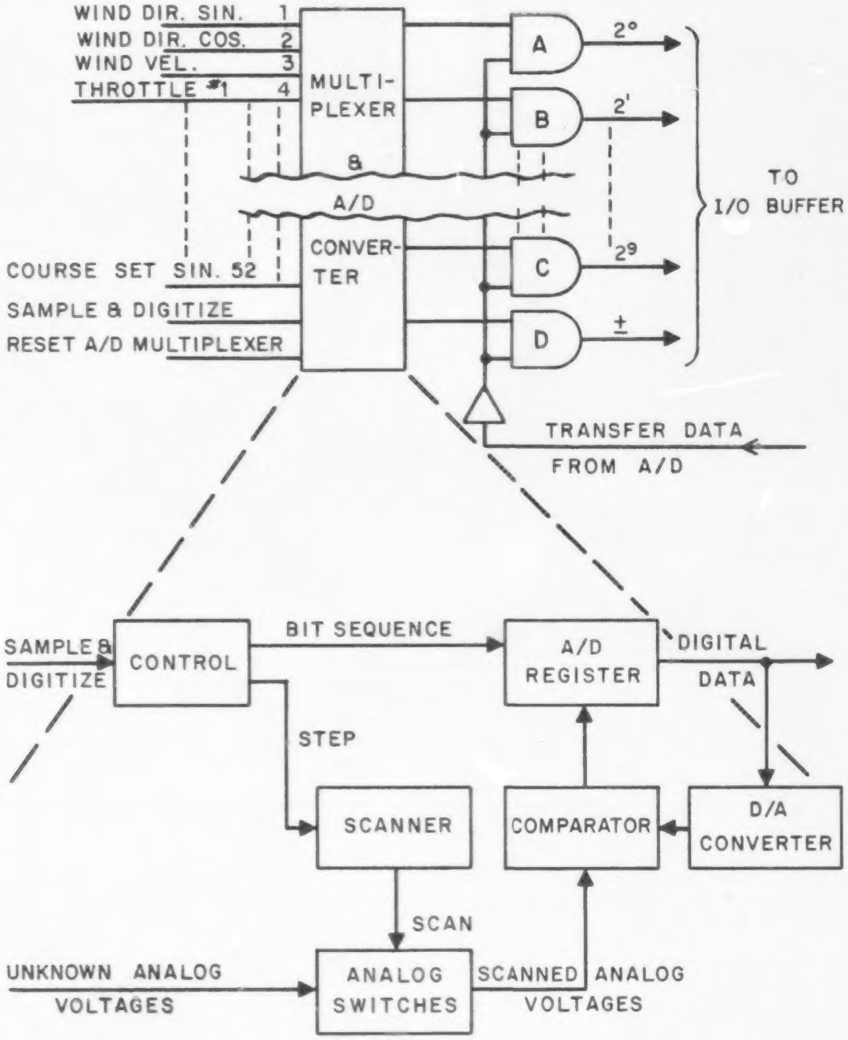

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Figure 8-11.—Block diagram, MULTICHANNEL A/D CONVERTER.

(3) A stable dc output amplifier
(4) A regulated reference voltage supply.

This converter operates in a manner similar to the digilog circuit described in detail in *Digital Computer Basics*, NAVTRA 10088-A, and therefore will be described here only at the block diagram level.

The input data register accepts 12 binary bits (including sign) in a parallel "jam" transfer (both assertion and negation are sent) from the I/O buffer. These 12 bits are gated into the register by the Transfer Analog (TA) signal. The output of the input data register is sent to the summarization network. The summing network is composed of transistor switches and a ladder

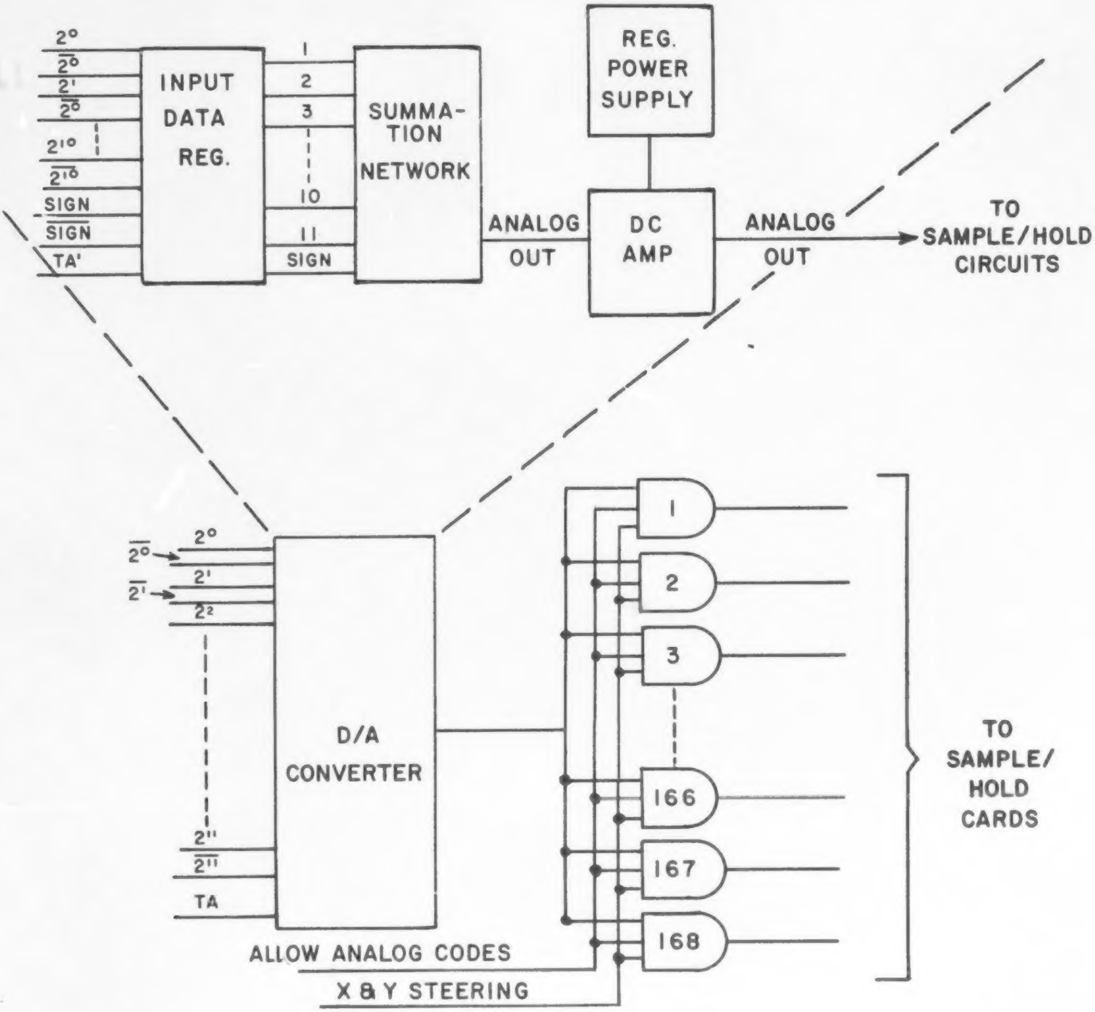

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Figure 8-12.—Simplified block diagram, digital to analog converter.

adder network (digilog circuit). The output of the A/D converter is a dc voltage that varies between +5 and -5 volts. This voltage is gated to one of 168 Sample and Hold cards by the Allow Analog codes, X and Y Steering signals, and other timing signals not shown (RS and OPP). The 168 separate Sample and Hold cards feed the various instruments/indicators in the instructor/student stations.

Sample/Hold

Some method had to be devised to maintain/sustain the output analog voltages between the periodic digital updating signals. Training Device manufacturers' most common solution to this problem is the Sample/Hold circuit. These circuits receive analog signals on a periodic sample basis and hold this information (maintain a signal level) unitl the next time data is available.

Figure 8-13 is a simplified diagram of the Sample and Hold circuit used in Device 2B21. This circuit consists of an input switch, a low-leakage storage capacitor, and a direct-coupled holding amplifier.

The input switch consists of a dual-emitter PNP transformer-driven transistor, Q1, which is turned on and off by a transistor driver, Q2. Transistor Q2 is normally biased off through resistor R3. A positive Sample pulse (summation of RS and the output of AND gate 1), of 50-microseconds duration is applied to Q2's base, turning it on. The resultant pulse in the collector circuit is coupled through a pulse transformer to the base-collector terminals of Q1 causing it to conduct and apply the sampled potential across the storage capacitor, Cl.

The holding amplifier is a direct-coupled multistage amplifier having an open-loop gain of 1,250. Very high input impedance is obtained by the use of an FET differential amplifier in the first stage. Further amplification takes place in a second silicon PNP differential stage.

Field-effect transistors (Q3A and Q3B) were selected for the first differential amplifier stage because of the very high input impedance requirement. The first stage has a voltage gain of approximately 6. The second differential amplifier, composed of Q4 and Q5, has a voltage gain of 210. Since the sample data input is ±5

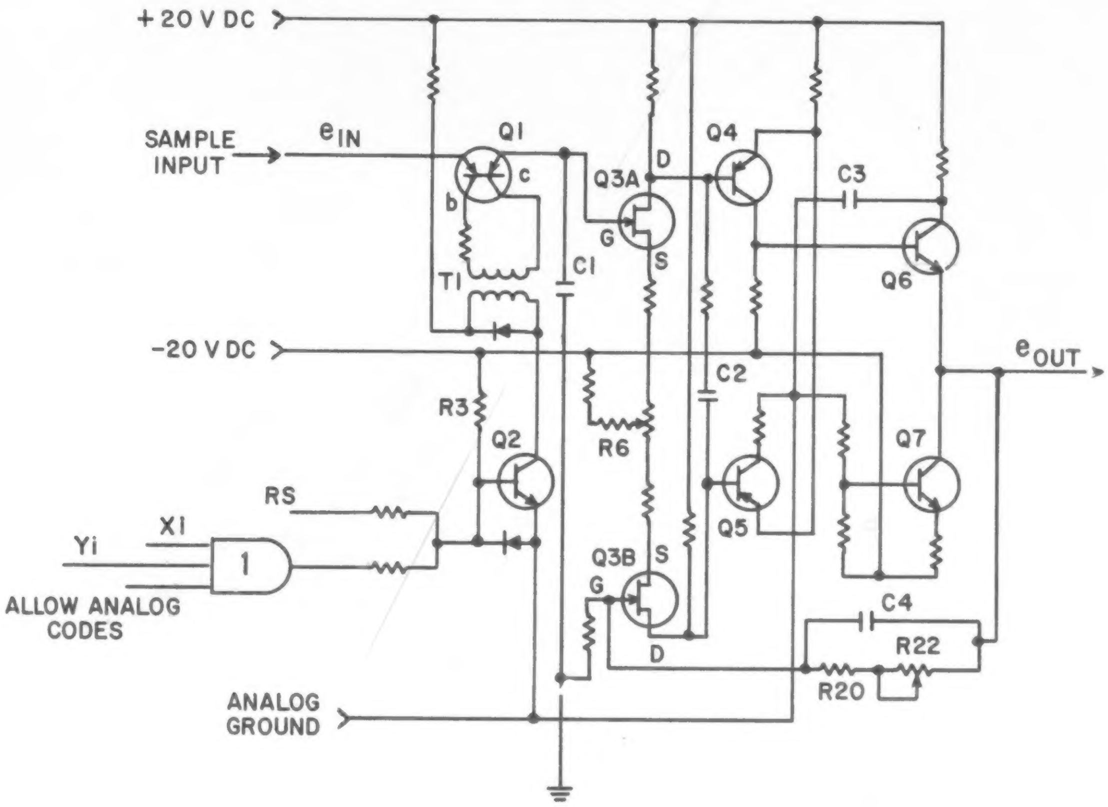

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Figure 8-13.–Simplified sample and hold circuit.

volts, and the output requirement is ±10 volts, the holding amplifier must have a gain of 2. This is attained by closing the loop and adjusting R22 until R22 + R20 = R6.

The output stage is made up of an emitter-follower, Q6, and a constant-current source, Q7.

TRAINING VEHICLES

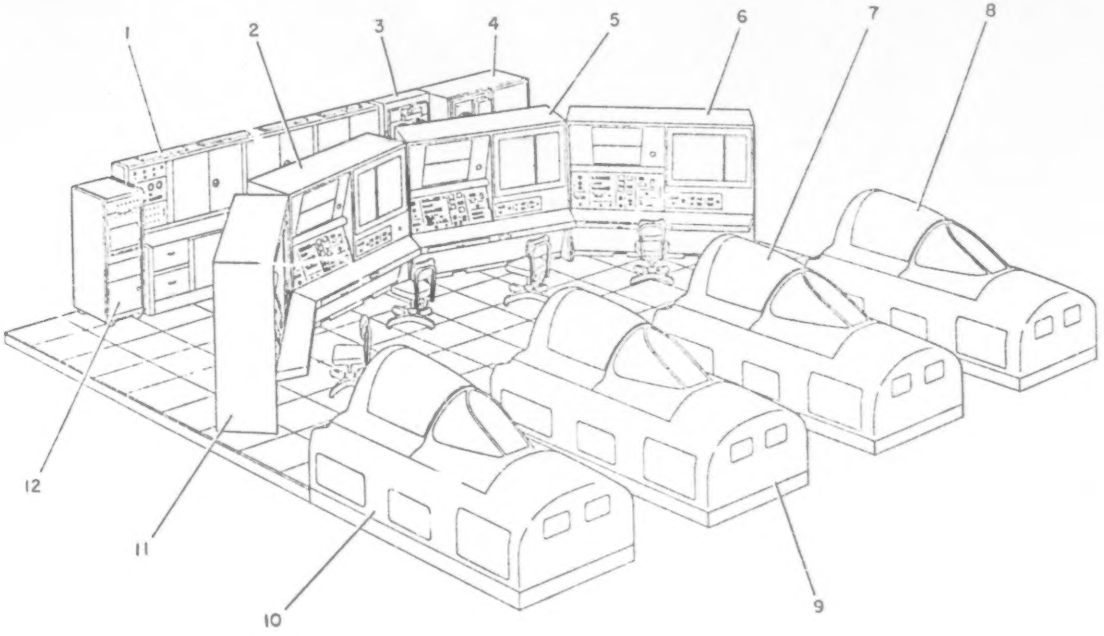
The term "training vehicle" is a term of convenience chosen to describe both the instructor/operator console and the student station, along with any motion system the simulator may have. These vehicles can be as complex as the S-3A Weapons System Trainer, with its six-degree-of-freedom motion platform, or as simple as the digitally stimulated headset and typewriter combination used to teach Morse code. The instructor/student positions may or may not be physically connected. Regardless, all training vehicles serve the same purpose; they provide the environment and necessary instructor control for training to take place.

DEVICE 2B21

Device 2B21, figure 8-14, is designed to familiarize flight students with the basic instrument flight skills. It simulates the T28B aircraft which is a single engine, two-place, fixed wing flight trainer. Device 2B21 has a fixed base and may have as many as 4 cockpits and instructor stations.

Trainee Station

Each of the (four possible) trainee stations is a reproduction of the forward cockpit of the T28B. The cockpit, instrument panels, seat, rudder pedals, and control stick are identical to that of the aircraft; however there are some differences such as the inclusion of the TACAN receiver. These differences do not detract from the intended training capabilities of the device.



1. Interface Rack
2. Instructor Console No. 2
3. Computer Operator Console
4. Computer
5. Instructor Console No. 3
6. Instructor Console No. 4
7. Cockpit No. 3
8. Cockpit No. 4
9. Cockpit No. 2
10. Cockpit No. 1
11. Instructor Console No. 1
12. Oscillograph Recorder

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Figure 8-14.—Basic instrument flight trainer (multiple cockpit), Device 2B21.

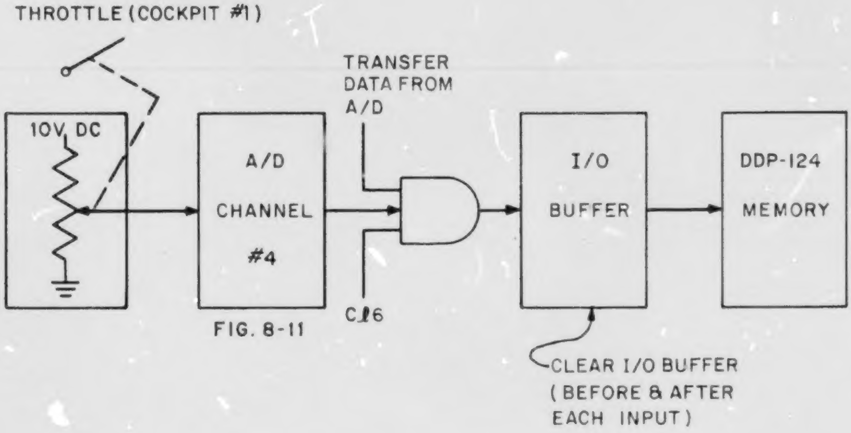

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Figure 8-15.—Analog-in.

For a better understanding of the simulation process (communication between computer and trainee station), analog I/O signals as well as digital I/O signals will be traced through the system. As far as digital simulation is concerned, most of the actual data flow for the various systems will be similar; therefore, single, representative examples will be given.

The throttle control is used as the example of an analog input. It operates as follows (fig. 8-15):

(1) The throttle controls the wiper arm of a pot which picks off a dc voltage between ground and 10 volts.

(2) This voltage is fed to channel 4 (for cockpit #1) of the A/D converter.

(3) The output of the converter (10 bits plus sign) is fed to the 11 MSDs of the I/O Buffer.

(4) The I/O Buffer output is fed into the main computer memory.

(5) Since the throttle has an effect on many systems, this data word, representing throttle setting, is used in a number of different aerodynamic equations.

Each of the other 51 analog input voltages is generated in a similar manner.

One of the systems affected by the throttle is the manifold pressure. The manifold pressure instrument, a dc device, is used as the example of an analog output signal (fig. 8-16).

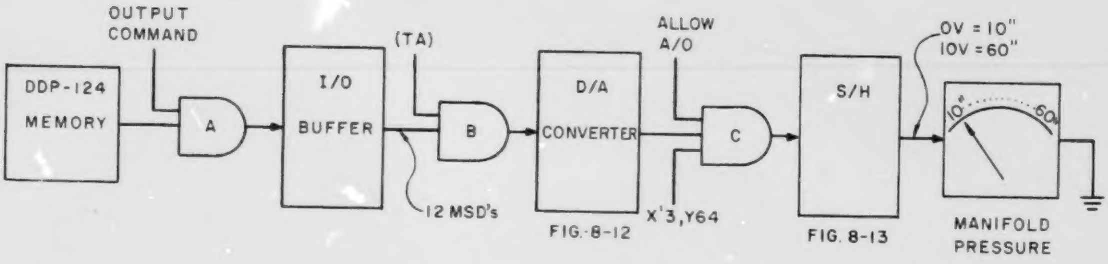
(1) The output for manifold pressure, a digital data word, is brought to the D/A converter from the I/O Buffer.

(2) The analog output of the converter is routed into the proper Sample/Hold card by gate C.

(3) Gate C has as inputs: Allow Analog Codes, X'3 Y64 steering signals, and an analog voltage.

(4) The output of this Sample/Hold card, a dc voltage that varies between 0 and 10 volts, is fed to the manifold pressure gauge.

All of the analog circuits that feed dc type instruments operate in a similar manner. However, there are synchro instruments (tachometer) that require two voltages (S1 and S2). With this type of synchro driven device two dc output voltages are fed to two Sample/Hold



244.167

Figure 8-16.—Analog-out.

cards. The outputs of these cards are fed to a synchro direct drive card and then to the synchro driven instrument.

Many inputs and outputs found in digital simulators are discrete in nature and require no conversion. Examples of these digital signals are switch positions (on, off), lighting an indicator lamp (providing a ground or voltage), and digital, frequency select switches. The devices used in digital to digital communications are decoding networks and digital multiplexing circuits. A digital multiplexer is a device that acts as a single-pole multiposition switch, passing information in one direction only.

The signal from the speed brakes (fig. 8-17) is used as the example of one of the 63 digital inputs (15 for each cockpit and 3 for the MDU).

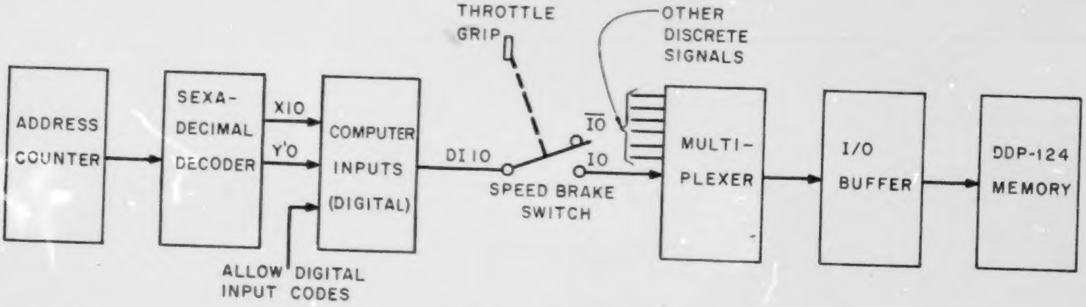
(1) The address counter and sexadecimal decoder send a decoded X10 and Y'0 to the computer input circuitry where they are ANDed with Allow Digital Input Codes.

(2) When all three signals are true, pulse DI10 is generated and sent to cockpit #1 to pulse or interrogate the speed brake switch. Note: Signal DI10 is labeled Cockpit #1 system discretes, and is used to pulse a number of other discrete functions.

(3) If the switch is closed, the pulse is felt as signal I0 in the multiplexing logic.

(4) The multiplexing logic provides the bus circuitry and gates, necessary to route this I0 signal, along with other discrete signals (ignition switch, brakes, etc.) to the I/O Buffer.

(5) This packed word is then sent to computer memory.



244.168

Figure 8-17.—Digital-in.

194

Digital outputs are generated when the computer outputs a packed word to the I/O Buffer. The packed word is first decoded and then used to energize relays and illuminate indicator lamps.

The signal from the wheels indicator (fig. 8-18) is used as an example of one of the 27 digital outputs (6 for each cockpit and 3 for the MDU).

(1) The computer outputs a word from memory to the I/O Buffer.

(2) An Allow Digital Output Codes signal and an address register decode (X and Y steering signal) of X5 Y'0 are ANDed in the digital output decoding section to produce a DO5 signal (Cockpit #1 discretes).

(3) This DO5 signal is ANDed with different I/O Buffer bits to produce various discrete signals to cockpit #1.

(4) For the wheels indicator, DO5 is ANDed with bit 2^8 and, if both signals are logic 1, F/F 1 sets.

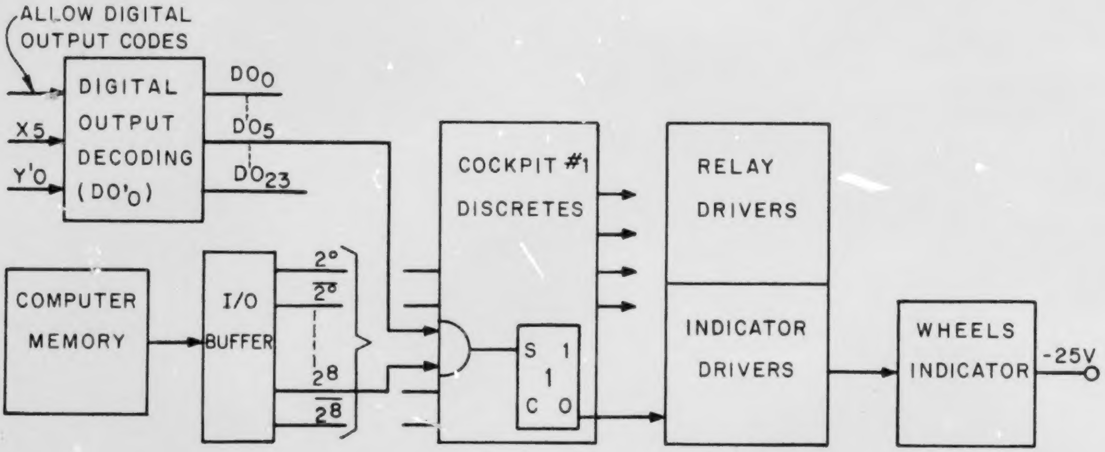
(5) The clear side of the F/F is sent to an indicator driver where the signal is inverted. The output provides a ground to the wheels indicator.

Instructor Station

The instructor station, figure 8-14, consists of a cabinet housing containing a control panel and a recorder. The control panel contains controls for introducing various malfunctions and environmental conditions, and the necessary indicators for monitoring cockpit indicators and trainee activities. Such controls and indicators are found on all devices whether they are flight trainers, submarine diving trainers, or surface attack trainers. Analog and digital signals are processed for the instructor station just as they were for the trainee station.

SYSTEM OPERATION

The digital computers utilized in training device simulators are operated as "Real Time" systems. A Real Time system, as defined in *Digital Computer Basics*, NAVTRA 10088-A, is a control system that processes the data in time with a physical process so that the answers obtained are useful in controlling that same process. This "physical process", for TDs, is the system simulated, e.g., submarine, ASW system, etc.



244.169

Figure 8-18.—Digital-out.

Examples of Real Time processing were presented earlier in this chapter when the various I/O signals were traced through the system. This signal processing was described from a hardware aspect, i.e., circuits, block diagrams, timing diagrams, etc. The next section describes system operation from another aspect, software.

SOFTWARE

Recall from *Digital Computer Basics*, NAVTRA 10088-A, the definition of software as being, "A set of computer programs, procedures, and documentation concerned with the operation of a data processing system." The Naval Training Equipment Center specifies, in various Data Item Descriptions (DIDs), the complete software that will accompany each training device utilizing a digital computer. The two major types of documentation are (1) the commercially available test, maintenance, and utility object programs and documentation, and (2) contractor-provided program tapes and listings developed specifically for the operation, maintenance, and modification of the digitally activated training device. The following programs are included in the latter category: Main Trainer Program, Daily Readiness Check Program, Trainer System Utility Program(s), Trainer System Test Program(s), and a Trainer Debug Program. Of these programs, the Main Trainer Program is the one discussed here.

Main Trainer Program

The Main Trainer program, represented in figure 8-19(1A), is written from algorithms that describe the real world situation to be simulated. For example, if a simulation of the SSN 688 submarine diving and control station is desired, a program will be written from mathematical equations that describe the dynamic characteristics of this submarine.

The Naval Training Equipment Center has specified general purpose digital computers as the type to be used in digital simulation systems. This means the same model of computer used in the simulation of the SSN 688 diving and control station could be used in a basic flight navigation trainer. An inspection of Appendix I will show this is in fact the case with Devices 21B56D and 2B21.

Figure 8-19(1B) is a generalized, simplified diagram depicting the cyclic operation of a main trainer (simulation) program. All simulator systems have some method of generating Real Time interrupt signals that are sensed by the computer. Once the computer receives an interrupt signal, it will execute the main trainer program, or at least a part of it. This simulation program is performed in modules that include: (1) digital input and output routines, (2) analog input and output routines, and (3) the actual simulation routines of the system being simulated. Once the simulation modules have been executed, the program loops on a wait (waste time) routine until the next interrupt occurs. At that point another cycle begins. While few simulator programs operate precisely as that shown in the figure, all simulator programs are executed in a cyclic manner.

The main trainer program for Device 2B21 does, in fact, operate as shown in figure 8-19(1B). This program is explained in the following discussion, using figure 8-20.

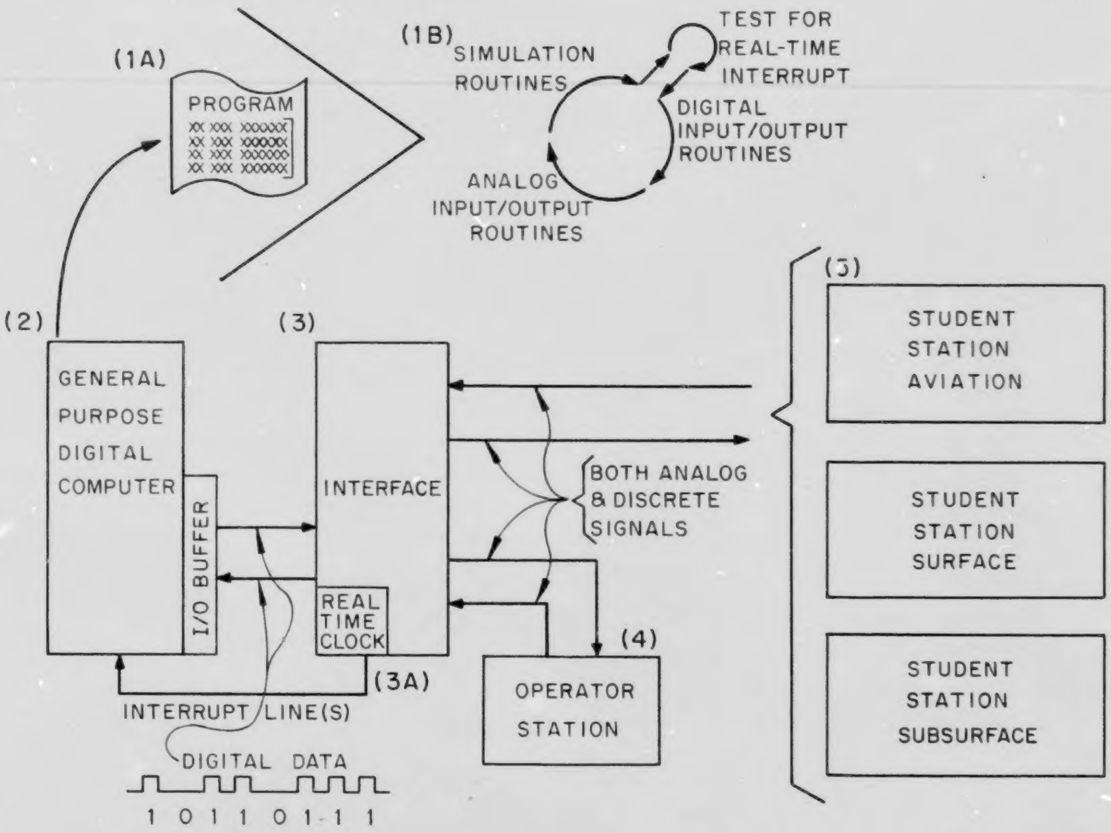
1. The program is initialized (housekeeping routines are performed—disable I/O buffer, inhibit I/O interrupt, etc.).

2. The Real Time Clock is started. The Real Time Clock is a one-shot multivibrator that provides a 50 millisecond delay before it sets a high speed flip/flop. The output from the F/F is then sent to the computer as an Interrupt #20. The Real Time Clock sets the overall main trainer program iteration rate.

3. The computer resets the real time F/F with an acknowledge (ACK) signal, and control is transferred to the executive routine with a jump command.

4. The executive routine contains all of the program modules necessary to simulate the basic flight navigation systems.

   a. Prior to entering these modules, a test is performed to see if the time allotted for



244.170

Figure 8-19.—System operation (software).

the previous execution of the major simulation subroutines has been exceeded. If the error flag is set the computer halts.

b. The sense switches are checked. If none are set, the error flag is set, preventing any error from being registered during the run, and the Real Time Clock is started.

c. A jump-store command is executed to the update synchro subroutine. New values (sine-cosine) are computed for all the synchros, and then the subroutine returns control to the main flow of the program.

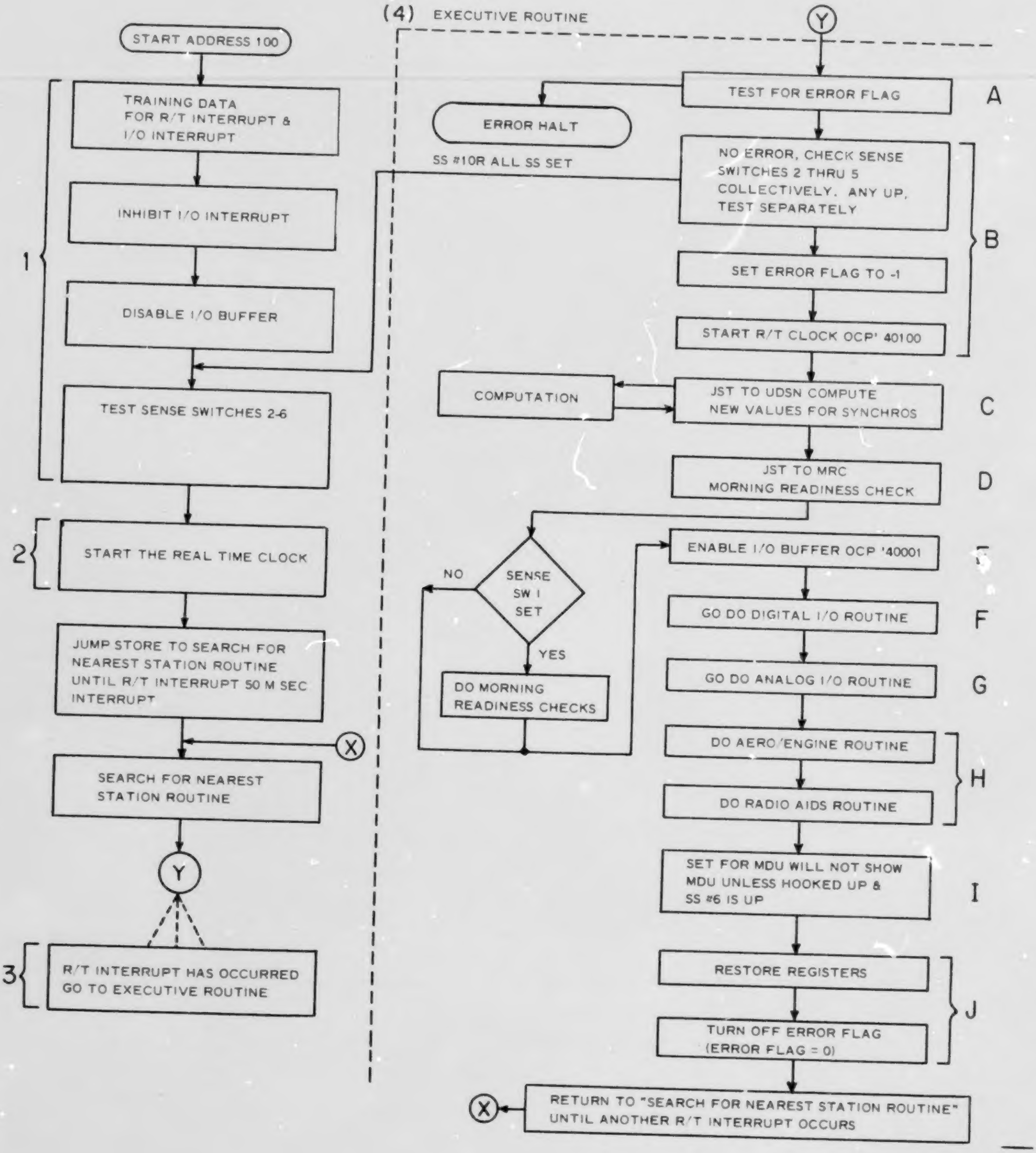
d. Another jump-store takes the program to a test for the morning readiness check (MRC). If true, the subroutine for the MRC is performed; if false, a return to the main flow of the program is executed.

e. At this point the I/O buffer is enabled in preparation for the two I/O routines.

f. The digital I/O routine is performed, bringing in 63 signals and sending out 24.

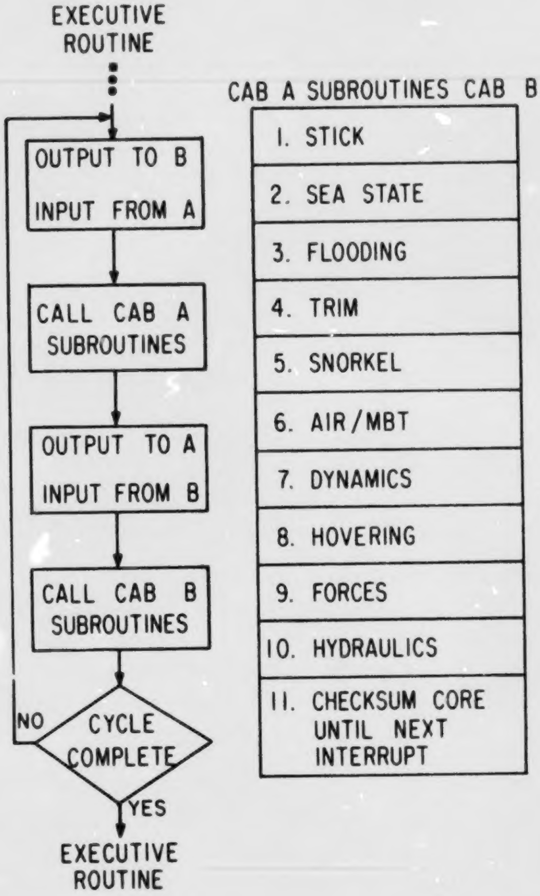
g. The analog I/O routine is performed next, bringing into the computer (after conversion) 52 analog inputs and outputting (after conversion) 168 analog signals.

h. Based on this latest information, which has just been stored in memory, two


START ADDRESS 100
TRAINING DATA FOR R/T INTERRUPT & I/O INTERRUPT
INHIBIT I/O INTERRUPT
DISABLE I/O BUFFER
TEST SENSE SWITCHES 2-6
1
2
START THE REAL TIME CLOCK
JUMP STORE TO SEARCH FOR NEAREST STATION ROUTINE UNTIL R/T INTERRUPT 50 M SEC INTERRUPT
X
SEARCH FOR NEAREST STATION ROUTINE
Y
3
R/T INTERRUPT HAS OCCURRED GO TO EXECUTIVE ROUTINE
(4) EXECUTIVE ROUTINE
Y
TEST FOR ERROR FLAG
A
ERROR HALT
SS #10R ALL SS SET
NO ERROR, CHECK SENSE SWITCHES 2 THRU 5 COLLECTIVELY. ANY UP, TEST SEPARATELY
B
SET ERROR FLAG TO -1
START R/T CLOCK OCP' 40100
COMPUTATION
JST TO UDSN COMPUTE NEW VALUES FOR SYNCHROS
C
JST TO MRC MORNING READINESS CHECK
D
NO
SENSE SW 1 SET
YES
DO MORNING READINESS CHECKS
ENABLE I/O BUFFER OCP '40001
E
GO DO DIGITAL I/O ROUTINE
F
GO DO ANALOG I/O ROUTINE
G
DO AERO/ENGINE ROUTINE
DO RADIO AIDS ROUTINE
H
SET FOR MDU WILL NOT SHOW MDU UNLESS HOOKED UP & SS #6 IS UP
I
RESTORE REGISTERS
TURN OFF ERROR FLAG (ERROR FLAG = 0)
J
X
RETURN TO "SEARCH FOR NEAREST STATION ROUTINE" UNTIL ANOTHER R/T INTERRUPT OCCURS

244.171

Figure 8-20.—Flow chart—2B21 main program.



244.173

Figure 8-21.–Simplified flow chart, Device 21B56D.

major routines, aero/engine and radio aids, are executed.

i. If the memory display unit (MDU) is hooked up and sense switch #6 is set, a memory test program is performed.

j. At this point the simulation program is completed, the registers are restored, and the error flag is turned off.

k. Control is returned to an idle or waste time routine until another interrupt occurs.

Figure 8-21 is a simplified flow chart of the simulation modules used in the submarine diving and control trainer, Device 21B56D. There are two trainers (cabs) per device; one simulates the diving and control stations of the SSN 688, and the other is a composite simulation of a number of different classes of submarines.

Note from the simplified flow chart that this program operates considerably different in many respects from that of Device 2B21. Device 21B56D employs an executive routine to direct the simulation modules (subroutines) as to when and how they are to perform their function, whereas Device 2B21 does not have a separate executive routine, per se. Most of the newer devices are using the former method.

Another difference between the devices is the flow of information between computer and student stations. In Device 2B21, data for as many as four cockpits are inputed/outputed, and the simulation model computations are completed in a single pass through the executive program. In Device 21B56D, output is sent to one cab (B) while input is brought in from the other cab (A). Next, the eleven subroutine modules are sequentially called and executed. The eleventh subroutine, called "checksum core," is an "idle" routine that is performed until an interrupt occurs. At that time the I/O to the two cabs is reversed (in from B, out to A). At the completion of this I/O routine, cab B subroutines are called. While these subroutines have the same titles as those used by cab A, they are not identical programs, but are based on similar math models.

The similarities between the two programs are those found in all digital simulation systems. Namely, they both possess I/O and simulation routines and use interrupts as control signals.

CHAPTER 9

DIGITAL SYSTEMS TROUBLESHOOTING

Prior to the discussion of troubleshooting digital simulator systems, background information is presented covering an introduction to the field of microelectronics—those components used in the construction of new simulator systems. This information is followed by a discussion of the techniques and equipments employed in the maintenance of digital integrated circuits.

MICROELECTRONICS

Microelectronics is the general name given to extremely small electronic components and circuit assemblies, manufactured by thin-film, thick-film, or semiconductor techniques. The terms integrated circuits and microelectronics are sometimes used interchangeably, but this is not entirely correct. An integrated circuit is a special case of microelectronics and refers to a circuit that has been fabricated as an inseparable assembly of electronic elements in a single structure which cannot be divided without destroying its intended electronic function. Thus, integrated circuits belong to the general category of microelectronics, but all microelectronic units are not necessarily integrated circuits.

There are two basic approaches to microelectronics—monolithic integrated circuits and film circuits. In monolithic integrated circuits, all circuit elements, both active and passive, are simultaneously formed in a single wafer of silicon by a diffused planar technique. The elements are interconnected to form the required electronic circuit by metallic strips deposited onto the oxidized surface of the silicon wafer using evaporation techniques. This technique is discussed in detail in the next section. Film circuits are microminiature electronic circuits fabricated by forming the passive electronic components and metallic interconnections directly on the surface of an insulation substrate and subsequently adding the active semiconductor devices, usually in discrete wafer form.

The two types of film circuits are thin-film and thick-film. In thin-film circuits the passive components and interconnection wiring are formed on glass or ceramic substrates using evaporation techniques. The active components (transistors and diodes) are fabricated as separate semiconductor wafers and assembled into the circuit. Thick-film circuits are prepared in a similar manner except the passive components and wiring pattern are formed by silk-screen techniques on ceramic substrates.

Other integrated circuits are produced using a combination of techniques. In multichip circuits, the electronic components for a circuit are formed in two or more silicon wafers (chips), and the chips are mounted side by side on a common header. Some interconnections are included on each chip, and the circuit is completed by small-diameter gold wiring between the chips. Hybrid integrated circuits are combinations of monolithic and film techniques, in which the active components are formed in a wafer of silicon using the planar process, and the passive components and interconnection wiring pattern are formed on the surface of the silicon oxide which covers the wafer, using evaporation techniques.

INTEGRATED CIRCUITS

The current trend of producing a number of circuits on a single chip further increases the packaging density of electronic circuits while reducing the size, weight, and number of connections in individual systems. Improvements in reliability, logistics, and system capability are being realized.

The packaging density of microelectronic circuits is best demonstrated by comparison of a conventional J-K flip-flop circuit incorporating solid state discrete devices and the same type of circuit employing integrated circuitry. The conventional circuit depicted schematically in figure 9-1 would require approximately 40 separate discrete elements, 200 connections, 40 hermetic seals, and 300 separate processing operations–with each operation, seal, and connection representing a possible source of failure. However, if all the elements of this circuit are integrated in one chip of silicon, the number of connections drops to approximately 14, because all circuit elements are intraconnected inside the package by a process known as vapor metalization; instead of 40 hermetic seals there is 1, and the 300 processing operations are reduced to approximately 30. Figure 9-2 presents a size comparison of a discrete J-K flip-flop circuit and an integrated circuit of the same type.

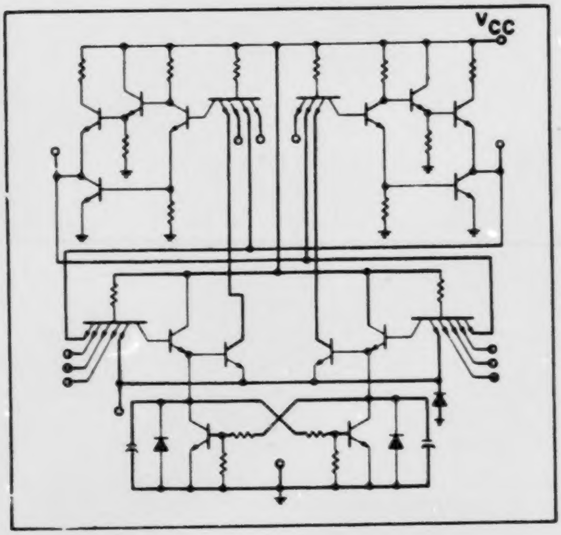


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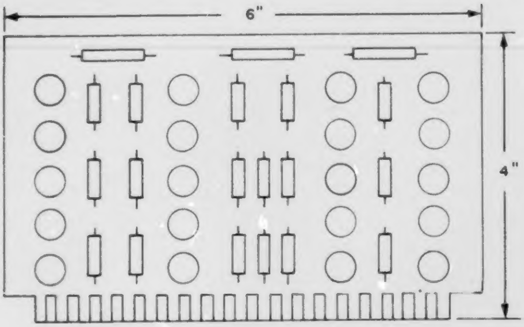
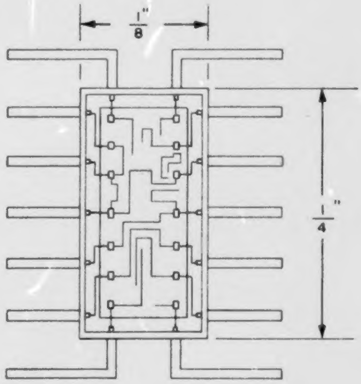
Figure 9-1.–Schematic of a J-K flip-flop.



(A) DISCRETE CIRCUIT



NOTE: NOT TO SCALE

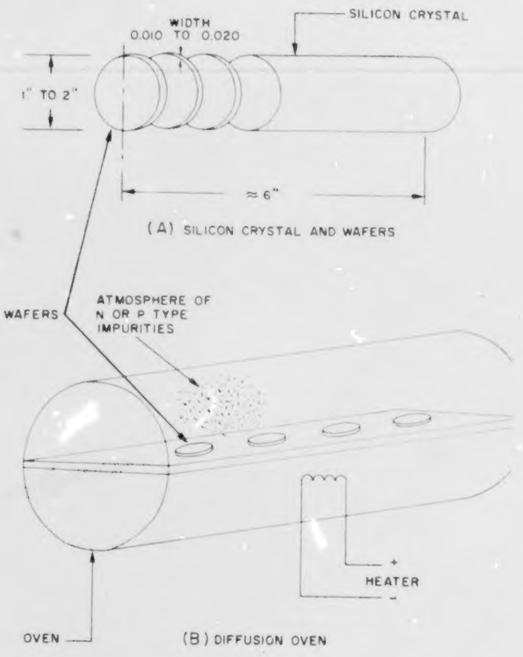
(B) INTEGRATED CIRCUIT

162.83

Figure 9-2.–Size comparison between a discrete and an integrated circuit J-K flip-flop.

Before the actual fabrication of the integrated circuit begins, the silicon crystal must be sliced into paper-thin wafers (fig. 9-3(A)). The wafers must be lapped and polished on the side used for the active elements. Unless special processing is involved, the back side of the wafer is left in the lapped state.

Both sides of the wafer are lapped simultaneously with an abrasive (usually aluminum oxide) until all visible traces of the saw cuts are removed. One side of the wafer is then polished several times with slurries of abrasive grits. A grit of smaller size is used for each succeeding polishing step. Finally, the



162.84

Figure 9-3.—Diffusion method.

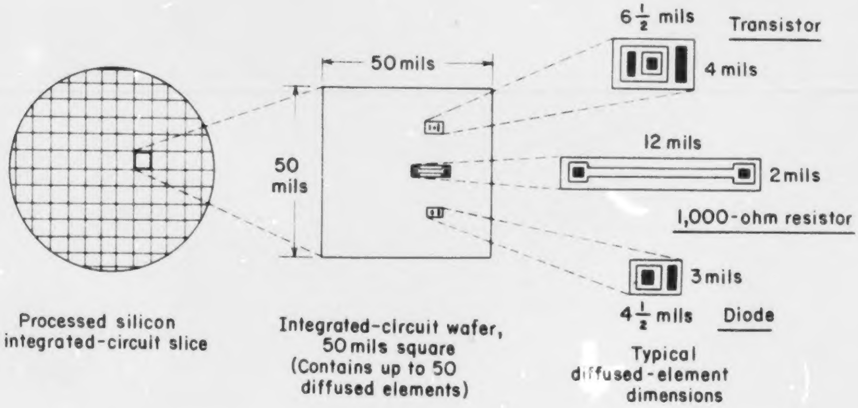
wafer is chemically etched to remove any irregularities in the surface resulting from the last polishing step.

The diffusion process begins when the highly polished silicon wafer is placed in an oven (fig. 9-3 (B)) containing impurity atoms which yield the desired electrical characteristics. The concentration of impurity atoms diffused into the wafer can be controlled by controlling the temperature of the oven and the time the silicon wafer is allowed to remain in the oven. When the wafer has been uniformly doped the fabrication of semiconductor devices may begin.

Both the passive elements (resistors and capacitors) and the active elements (transistors and diodes) are formed in the silicon slice by diffusing impurities into selected regions to modify the electrical characteristics and, where necessary, to form isolating p-n junctions. The various elements are designed so they can be formed simultaneously by the same sequence of diffusions. All process operations are carried out on top of the silicon slice, and all the element contact regions are formed on this same surface so they can be interconnected to form the complete electronic circuit by evaporating a metallic wiring pattern on top of the silicon oxide which covers the surface between the contact areas.

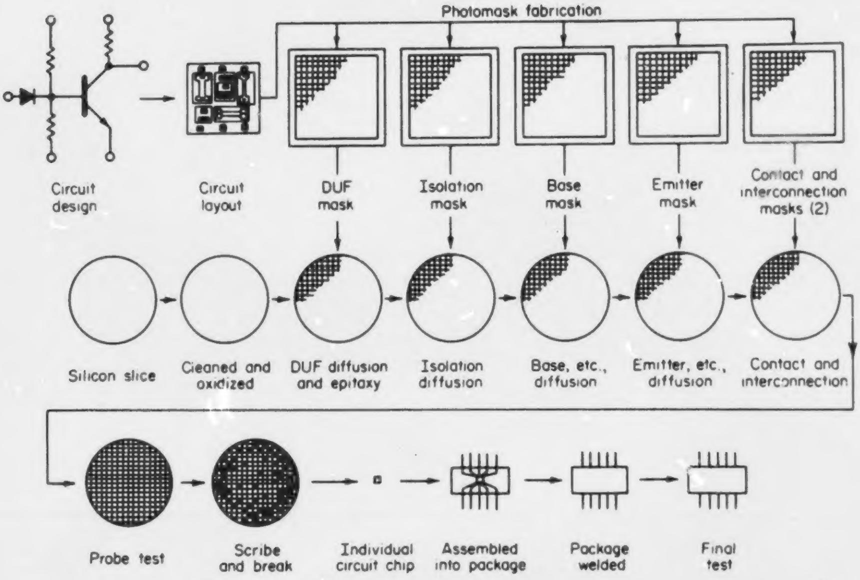
The processes of selective oxide removal, diffusion, and metallization are carried out on whole silicon slices. On each slice the same circuit pattern is repeated numerous times. For example, with a typical integrated circuit having dimensions 50 mils square, a single slice of silicon, 1.5 in. in diameter, will contain about 500 circuits, which are all processed at the same time. Figure 9-4 is an illustration of this construction.

The general sequence of monolithic integrated circuit fabrication is illustrated graphically in figure 9-5. The first step is the breadboard design of the electronic circuit using discrete components. The circuit is designed to perform the required function and ensure the values of the circuit elements are compatible with the diffusion processes. Next, the circuit elements are designed dimensionally and the complete circuit laid out in a geometric pattern. This is usually carried out by drawing the layout about 500 times full size; that is, a wafer 50 mils square is drawn about 2 ft. square. From this drawing, a series of related drawings are prepared, one for each of the oxide-removal steps, and then each of these drawings is reduced to life size by a series of photographic processes. At the same time as the final reduction to life size, the pattern is repeated by indexing the photographic plate under the image in a step-and-repeat sequence, so for each oxide-removal step, a master photographic mask is obtained, containing a matrix of the circuit patterns in precise location over an area greater than the slices to be processed. From the master photomasks, copies are prepared by contact printing, and these copies are used to selectively expose the photoresist during the oxide removal steps. (The photoresist is an organic substance which polymerizes when exposed to ultraviolet light, and then, in that form, resists attack by acids and solvents.)


6 1/2 mils
Transistor
4 mils
50 mils
50 mils
12 mils
2 mils
1,000-ohm resistor
3 mils
4 1/2 mils
Diode
Processed silicon integrated-circuit slice
Integrated-circuit wafer, 50 mils square (Contains up to 50 diffused elements)
Typical diffused-element dimensions

244.174

Figure 9-4.—Typical integrated circuit details.



244.175

Figure 9-5.—Monolithic integrated circuit fabrication sequence.

Starting with a silicon slice about 1.5 in. in diameter and 12 mils thick, the processes of oxidation, selective oxide removal, diffusion into the windows so formed, and contact metallization are carried out using the planar process. (In the planar process all the regions of the various elements come to the same plane surface, with the junctions between the regions protected at the surface by a layer of material such as silicon oxide.) The photomasks define the precise location of each element for oxide removal, and the diffusions modify the properties of the silicon within these locations to form the different elements.

THIN AND THICK FILM CIRCUITS

Film circuits differ from the integrated circuits described in the preceding paragraphs in that instead of being diffused into the substrate, components are layered on the substrate material (usually ceramic) by deposition, screening and etching, or a combination of these processes.

Only passive devices are produced by this technique since it does not lend itself to the production of active components. Active components are attached and interconnections between components made in much the same way as leads are bonded to integrated circuits (ICs) or transistors.

HYBRID CIRCUITS

A hybrid microcircuit is one that is fabricated by combining two or more circuit types (i.e. film circuits and semiconductor circuits) or a combination of one or more circuit types and discrete elements (fig. 9-6). The primary advantage of hybrid microcircuits over other microcircuits is design flexibility. Hybrid microcircuits find wide application in specialized applications, such as low-volume and high-frequency circuits.

Several elements and circuits are available for hybrid applications. These include discrete components that are electrically and mechanically compatible with integrated circuits. They may be used to perform functions supplementary to ICs and can be handled, tested, and assembled with essentially the same technology and tools.

Complete circuits are available in the form of uncased chips (unencapsulated IC dice). These chips are usually identical to those sold as part of the manufacturer's regular production line. They must be properly packaged and connected by the user if a high-quality final assembly is to be obtained.

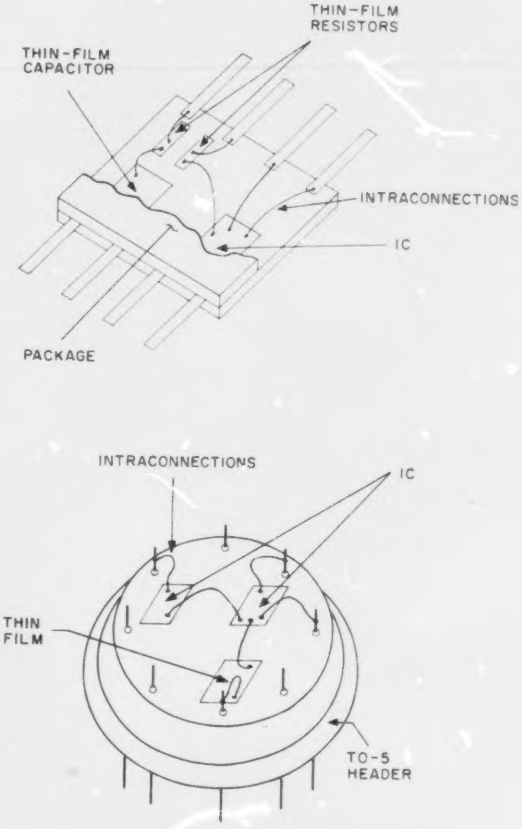


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Figure 9-6.—Hybrid circuit configuration.

DEVICE PACKAGING

Integrated circuit packages have evolved from the still-used transistor type (modified to include more leads), to the widely used flat pack, to the dual in-line package (DIP).

Modified TO-5 Package

"Modified TO-5" is a term used to describe a package having the same general appearance as a standard TO-5 transistor package but which has been modified by increasing the number of external leads and the dimensions of the package.

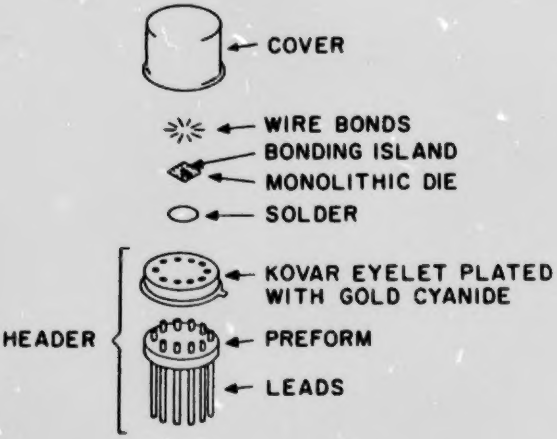

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Figure 9-7.–Exploded view of modified TO-5 package.

Modified TO-5 assembly methods are extensions of the techniques used in the production of standard transistor packages. Since the modified TO-5 package typically has 10 leads, compared with the 3 or 4 leads of the standard transistor package, its pincircle diameter is slightly larger (0.230 inch vs. 0.200 inch). The modified TO-5 package is shown in figure 9-7. Kovar, a nickel-iron alloy, is used for the leads and eyelet, and 7052 glass for the preform. The cover may be German silver, kovar, or nickel, but kovar is used most frequently because its coefficient of thermal expansion is similar to that of the glass preform, thus allowing a matched seal.

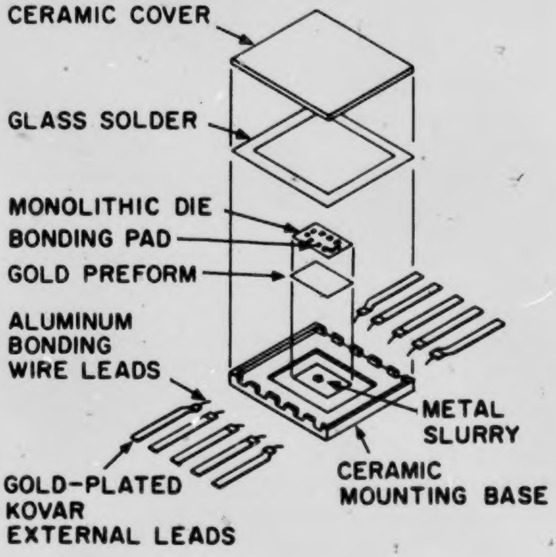
The glass preform and eyelet are assembled as shown in figure 9-7, and then sealed by fusion in a 1000° C oven. After it is sealed, the entire assembly, called the header, is cleaned and the leads are clipped to the desired length. The header is then plated with 0.001 inch of gold cyanide. The IC die is bonded to the header by (1) inserting a solder preform between the die and the header, (2) placing a weight on top of the assembly, and (3) heating the entire header to approximately 395° C so that the die, solder, and header are fuzed together.

With the chip firmly mounted in the package, the electrical connections from the circuit terminal pads on the chip to the package leads can be made. The most widely used method is thermal-compression bonding. Once the lead connections have been made, the final step in TO-5 packaging is to weld the cover to the header in a controlled atmosphere.

Flat Pack

Many types of integrated circuit flat packages are being produced in various sizes and materials. These packages are available as square, rectangular, oval, and circular configurations with 10 to 60 external leads and may be fabricated of metal, ceramic, epoxy, glass, or combinations thereof. Only the ceramic flat pack (fig. 9-8) will be discussed here, since it is representative of all flat packs with respect to general package requirements.

After the package leads are sealed to the mounting base, a rectangular area on the inside bottom of the base is treated with metal slurry to provide a surface suitable for bonding the monolithic die to the base. The lead frame is then cut away from the secured leads, and these leads and the metalized area in the bottom of



162.89

Figure 9-8.–Exploded view of ceramic flat pack.

the package are gold-plated. The die is then attached by gold-silicon eutectic (easily melted) bonding.

The die bonding step is followed by bonding gold or aluminum wires between the bonding island on the integrated circuit die and the inner portions of the package leads.

Following the wire bonding, a glass-solder preformed frame is placed on top of the mounting base. One surface of the ceramic cover is coated with Pyroceram glass, and the cover is placed on top of the mounting base. The entire assembly is placed in an oven at 450° C. This causes the glass solder and Pyroceram to fuse and seal the cover to the mounting base.

Dual In-Line

The dual in-line package (DIP) was designed primarily to overcome the difficulties associated with handling and inserting packages into mounting boards. Dual in-line packages are easily inserted by hand or machine and require no spreaders, spacers, insulators, or lead forming. It is also possible to field-service the devices with standard hand tools and soldering irons. Plastic dual in-line packages are finding wide use in commercial applications, and a number of military systems incorporate ceramic in-line packages.

The progressive stages in the assembly of a ceramic dual in-line package are illustrated in figure 9-9. The integrated circuit die is sandwiched between the two ceramic elements (A). The element on the left is the bottom half of the sandwich and will hold the integrated circuit die. The ceramic section on the right is the top of the sandwich; the large well protects the integrated circuit die from mechanical stress during sealing operations. Each of the ceramic elements is coated with low-melting-temperature glass for subsequent joining and sealing. The kovar lead frame is shown stamped and bent into its final shape (B). The excess material is intended to preserve pin alignment. The holes at each end are for the keying jig used in the final sealing operation. The lower half of the ceramic package is inserted into the lead frame (C). The die is mounted in the well and leads are attached. The top ceramic element is bonded to

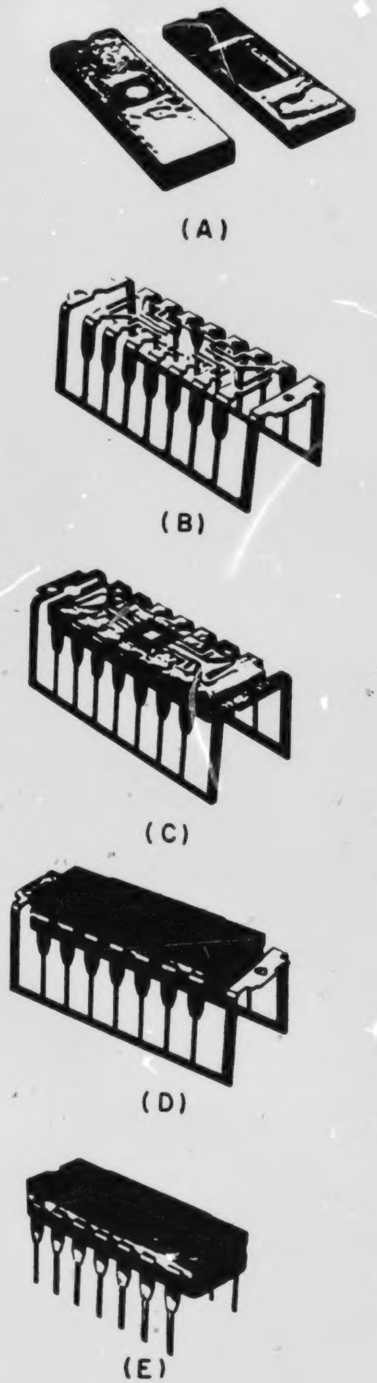


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Figure 9-9.—Dual in-line package assembly.

the bottom element (D) and the excess material is removed from the package (E).

The ceramic dual in-line packages are processed individually while plastic dual in-line packages are processed in quantities of two or more, in chain fashion. After processing, the packages are sawed apart. The plastic package also uses a kovar lead frame, but the leads are not bent until the package is completed. Because molded plastic is used to encapsulate the integrated circuit die, there may be no void between cover and die as is the case with ceramic packaging.

At present, ceramic dual in-line packages are the most common of the two package types found in Navy microelectronics systems.

DIGITAL INTEGRATED CIRCUITS

Digital Computer Basics, NAVEDTRA 10088-A, describes the following "families" of logic circuits: RTL, DTL, and DCTL. Since the publication of that manual, new families have evolved, e.g., the transistor-transistor logic (TTL) gates used in Device 2F101(T2C). Before these new logic families are discussed, it is appropriate to discuss the general terminology used to describe all logic families. These characteristics include logic voltage levels, threshold voltage, noise margins, operating speeds, fan-in and fan-out, operating temperature, and power dissipation.

Logic Voltage Levels

Logic circuits are normally connected in cascade; that is, the output from one gate is connected to the input of the following gate, and so on. Thus, the switching behavior of one circuit depends not only on its own output characteristic, but may also depend on the input characteristic of the next gate. Consider the simple case of one inverter circuit driving another as shown in figure 9-10. With the second transistor disconnected, the output of T1 will swing from V_{CE} (saturated), about .2 volts, up to V_{CC}. However, with the second stage connected, the positive voltage at the collector of T1 will be limited to that of the base-emitter voltage of transistor T2. Thus, the voltage swing at the output of transistor T1 will now be from .2 to .9 volts.

The load resistance R_L and the input characteristic of the base-emitter junction of transistor T2 together result in a combined load line for transistor T1 as shown in figure 9-11 (A). The forward-voltage transfer characteristic is shown in figure 9-11 (B). Note that the output swing of transistor T1, from .2 to .9 volts, gives satisfactory operating points for the input of T2, which in turn will give the same swing at its output when it is connected to the input of the next stage. The conditions for satisfactory switching between the two states are as follows: when T1 is saturated, its collector voltage must be low enough to keep T2 cut off; and when T1 is cut off, the base current of T2 must be high enough to saturate T2. The two operating points with this simple direct-connected circuit are well defined, the '0' state by the collector saturation voltage of the transistor (V_{CE}), and the '1' state by the base-emitter voltage of the transistor in the saturated condition (V_{BE}).

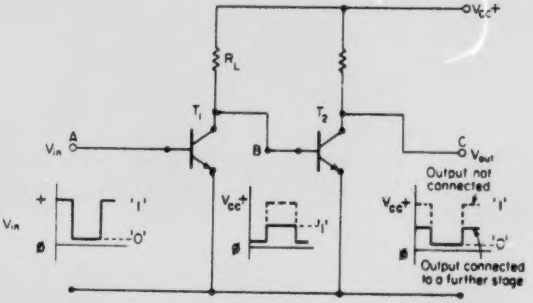

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Figure 9-10.—Direct-coupled inverter stages.

Threshold Voltage

Threshold voltage is defined as the voltage level at the input of a circuit, which will cause the circuit to change states. One approximation of this is the midpoint of the transistion between two states. This is the point V_t in figure 9-11B.

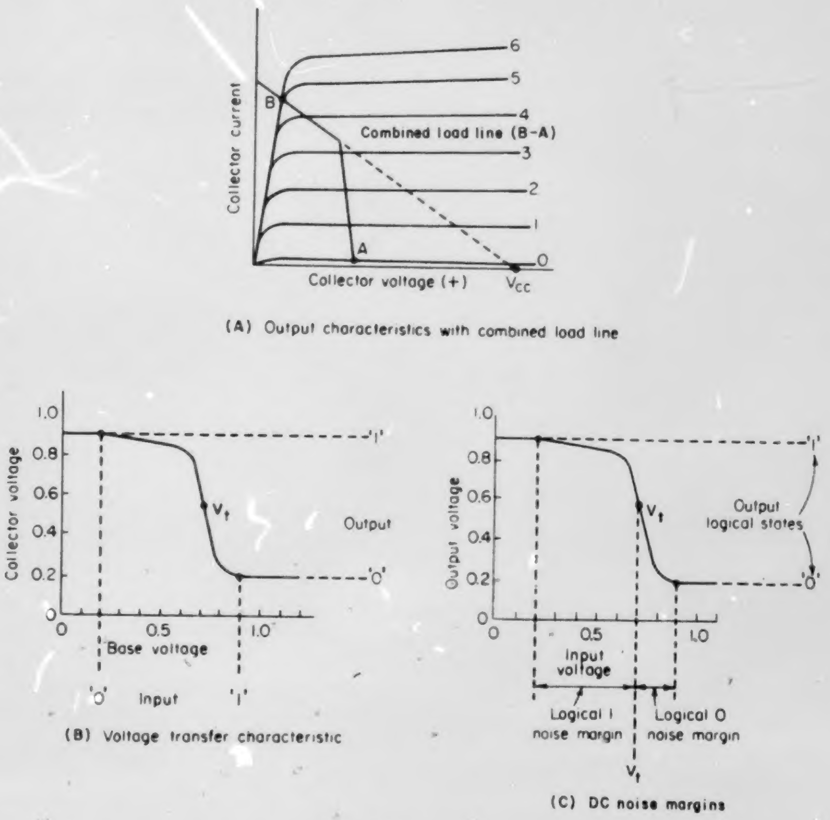

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Figure 9-11.—Direct-coupled circuit characteristics.

As was shown earlier, the value of the threshold voltage is partly dependent on the base-emitter characteristics. Since these characteristics change with temperature, the threshold voltage will also change with temperature. It will be seen later how the value of the threshold voltage also depends upon circuit arrangement.

Noise Margin

In logic systems, the word noise refers to any unwanted voltage (ac or dc) appearing at the input of a logic circuit. If such a noise voltage were high enough, it could cause the circuit to change state with no change in the input signal voltage. The difference between the operating input logic voltage level and the threshold voltage is called the noise margin of the circuit, i.e., the maximum value of noise voltage that the circuit can tolerate without changing states.

In practice, there are two values of noise margin associated with a circuit (fig. 9-11 (C)): (1) the difference between the input voltage necessary for a logic zero output and the threshold voltage (V_t), and (2) the difference between the input voltage necessary for a logic one output and the threshold voltage (V_t). As you will note in the figure, these two values are not equal. The noise margin for this circuit is specified by the smaller amount (logic zero) because this is the value that first affects the stability of the circuit. The latest logic circuits are being designed with approximately equal noise margins ("1" and "0") in order to give the most stable operation for a given total logic-voltage swing.

It is relatively straightforward to specify the dc noise margin of a circuit, but this is not the whole story. Noise can appear at the input to a logic circuit as short, transient voltage pulses. The ability of a circuit to withstand such transient noise voltages is called the ac noise margin or ac noise immunity. The ac value therefore depends on the shape and duration of the voltage pulses, and may be affected by stray capacitances; the ac noise margin is much more difficult to define and specify.

Operating Speed

It takes a finite time for a circuit to change from one logic state to the other. In a transistor, this time is that which is necessary for the base current to supply a charge to, or remove a charge from, the capacitive elements associated with the transistor structure, in order to produce the required voltage change at the output. In a circuit, additional time is required to charge any capacitance associated with the load. This time delay (between input and output) is called the propagation delay of the circuit. Delay values vary considerably depending on the particular circuit, but with integrated logic circuits the delay is usually in the range of 2 to 50 nanosec per gate. The overall propagation delay of a complete logic system will be the delay per gate multiplied by the number of gates in series.

An electric current is propagated along a wire at a rate of about 9 in. per nanosec. With discrete-component circuits, the time delay, due to the current traveling along the interconnecting wires, could be a significant part of the total circuit delay. However, with integrated circuits the interconnections are very short, and the time delay, due to current propagation, is usually negligible compared with the circuit delay.

Fan-in/Fan-out

The fan-in and fan-out of a logic gate are simply the maximum number of inputs it is designed to accept and outputs it is capable of driving, respectively. The fan-in is a simple matter of arranging for a circuit to have the required number of logic elements, each with an associated input. The fan-out is a more complicated matter. The subsequent circuits fed by the logic gate are all connected in parallel to its single output terminal, hence, all their inpedances appear in parallel across the output of the gate. Therefore, the driving gate circuit must be designed so its internal output impedance is low enough to allow the full logic-voltage swing to be produced across the low impedance that results from this parallel connected output.

Operating Temperature

All semiconductor devices are temperature sensitive. This is due primarily to the characteristics of the p-n junctions changing with temperature. Silicon transistors and diodes can operate satisfactorily with junction temperatures up to about 200° C; above this temperature the characteristics become so poor as to result in inferior performance. Diffused resistors may also change their value with change of temperature due to the thermal generation of carriers and the change in the mobility of the carriers. Integrated circuits intended for military applications are usually specified to operate over the ambient range of -55 to +125° C.

Power Dissipation

The power dissipation of a logic circuit is usually defined as the supply power required for the gate to operate with a 50 percent duty cycle, that is, equal times in the 0 and 1 logic states. The power dissipation of typical integrated logic circuits ranges from a few milliwatts to about 50 mw per gate, depending on the type of circuit. In general, high-speed circuits with short propagation delay require higher power.

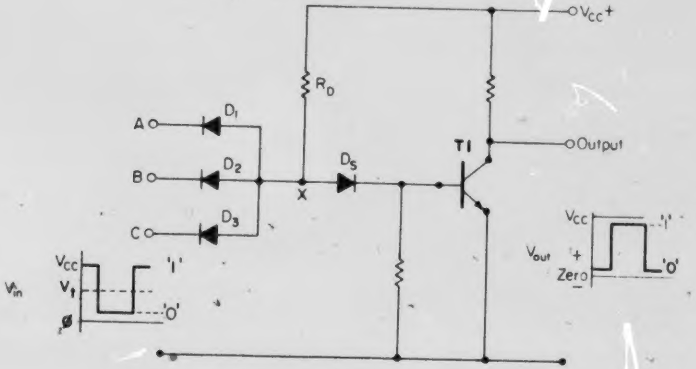
Logic Families

As stated earlier, several logic-circuit groups or families have been introduced. They differ primarily in the methods for carrying out the logic and the coupling to the inverter stages. For example, the transistor-transistor logic (TTL) uses a multiemitter transistor instead of the diodes found in DTL circuits. In emitter-coupled logic (ECL), the circuits are coupled by a common-emitter resistor, and complementary transistor logic (CTL) uses a combination of PNP and NPN transistors.

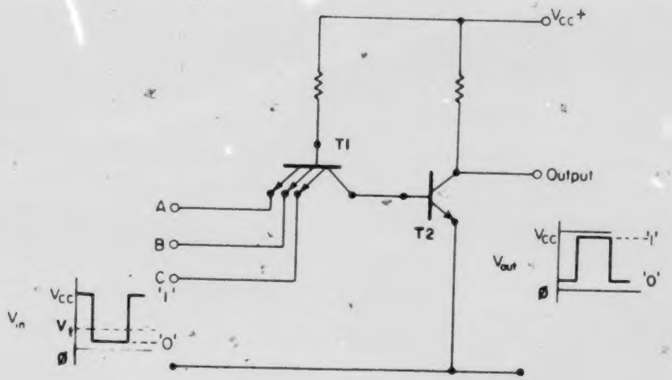
For each family, variations of a basic gate circuit are used to design a wide range of logic circuits with compatible input and output logical levels. In the design of a complete logic system, it is generally necessary to use logic circuits of one family only.

TRANSISTOR-TRANSISTOR LOGIC (TTL).—In the transistor-transistor logic circuit, a multiemitter transistor replaces the input diodes and the series diode of the DTL logic circuit as shown in figure 9-12. Each emitter-base junction (diode) serves as one input, and the base-collector junction (diode) operates as the series diode.

The operation of the circuit is similar to that of the DTL circuit. Suppose that all inputs are logical 1 at V_{CC} potential. All the emitter



(A) Basic DTL NAND circuit.



(B) Basic TTL circuit.

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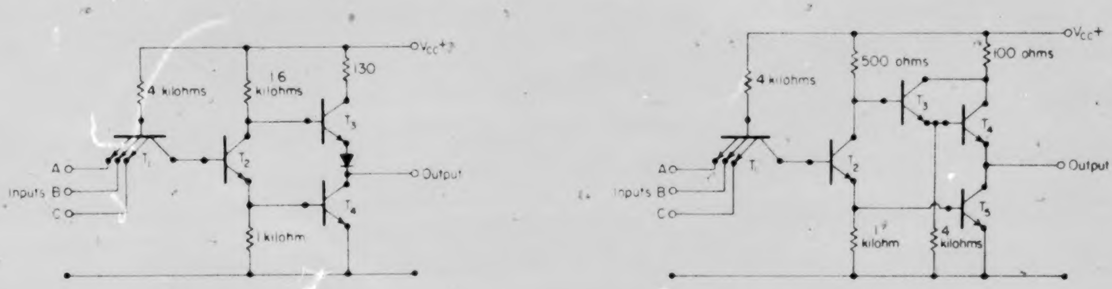
Figure 9-12.—TTL versus DTL.

junctions of transistor T1 (fig. 9-12 (B)) are reverse biased, but the collector junction is forward biased, and current flows through it to drive transistor T2 into saturation and give a logical 0 output. Now let any one of the inputs be logical 0 (near ground potential). The emitter of transistor T1 connected to that input is then forward biased, and current flows through it and causes the potential at the base of T1 to fall; transistor T2 is cut off, and the collector voltage rises to V_{CC} to give a logical 1 output.

The multiple-emitter transistor is economically fabricated in monolithic form. A single isolated collector region is diffused; a single base region is formed in the collector region; then the several emitter regions are diffused as separate areas into the base region.

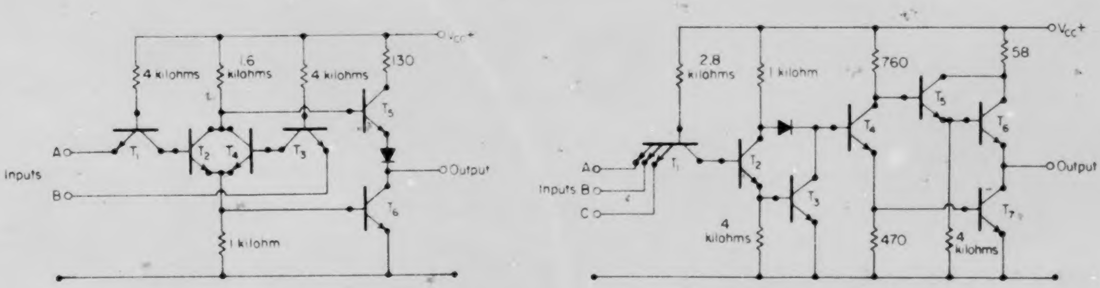
This logic circuit is used as the basis for a number of TTL logic gates. A full NAND gate is shown in figure 9-13 (A). An output stage is added to the basic logic circuit to give current-gain drive for switching in both directions. This results in a faster switching speed and a higher fan-out capability. Since the base-emitter junction of transistor T4 is in series with that of transistor T2, the threshold voltage is increased to about 1.4 volts, giving a noise margin in the order of 1.2 volts.

A TTL NOR gate is shown in figure 9-13 (B). The input logic circuit of T1 and T2 is duplicated by T3 and T4 with only one emitter input each to T1 and T3. The outputs of T2 and T4 are connected in parallel and fed to an output stage. If input A is a logical 1 (+V_{CC}), the T1 emitter-base junction will be cut off, and current will flow through the 4-kilohm resistor to drive T2 into saturation. Alternatively, if input B is at V_{CC}, T4 will be driven into saturation. Thus, if either A or B is positive (logic 1), current will flow through the common 1.6-kilohm load resistor and the common 1-kilohm emitter resistor of transistors T2 and T4 to drive the output stage and give NOR operation.



(A) TTL NAND gate

(C) TTL NAND power gate



(B) TTL NOR gate

(D) TTL AND gate

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Figure 9-13.–TTL logic family.

Figure 9-13 (C) shows a TTL NAND gate which has a power output stage to give a very low output impedance and allow a high fan-out, up to 30. By including an additional inverter stage, the circuit can be converted to an AND gate as shown in figure 9-13 (D).

The TTL circuit is very adaptable to all forms of integrated circuit logic and gives medium-cost circuits with high-noise margin, high operating speed, high fan-out, and reasonably low-power consumption.

EMITTER-COUPLED LOGIC (ECL).–A basic emitter-coupled logic gate is shown in figure 9-14. The emitters of logic transistors T1, T2, and T3 are coupled to the emitter of a reference transistor T4. The common-emitter resistor R_E is large enough to act as a constant current source. The base of transistor T4 is connected to a reference voltage V_{BB}. If the inputs are all near ground potential (logic zero), transistors T1, T2, and T3 will all be cut off, no current flows through R1, and the common collector potential rises toward V_{CC}. This drives transistor T5 into conduction, and the output from the emitter of T5 goes positive to give a logical 1 output.

If one of the inputs is made positive, above the value of V_{BB}, to give a logical 1 input, current will flow through the associated transistor, causing the collector potential and the output voltage from T5 to fall to give a logical 0 output. Since resistance R_E constitutes a constant current source, the current through the logic transistor increases, as the current through the reference transistor decreases. The switching threshold voltage is equal to the reference voltage V_{BB}. The use of emitter coupling in both the logic stage and output stage prevents the transistors from going into saturation, and, as a result, the switching speed is very fast, typically only a few nanoseconds. The power dissipation, however, is relatively high, typically 50mw. The input threshold voltage, being equal to the reference voltage V_{BB}, is well defined, but the logic 0 and 1 levels cannot be defined as precisely as in saturated circuits. The use of an emitter-follower circuit for the output gives a very low output impedance, allowing a very high fan-out, 20 to 30.

COMPLEMENTARY-TRANSISTOR LOGIC (CTL).–This is a family of logic circuits using an emitter-coupled AND gate with a combination of PNP and NPN transistors. A typical example is shown in figure 9-15. With all inputs at V_{CC}, logical 1, the PNP input transistors are cut off, no current flows, and the common-emitter voltage rises toward V_{CC}. Base current flows

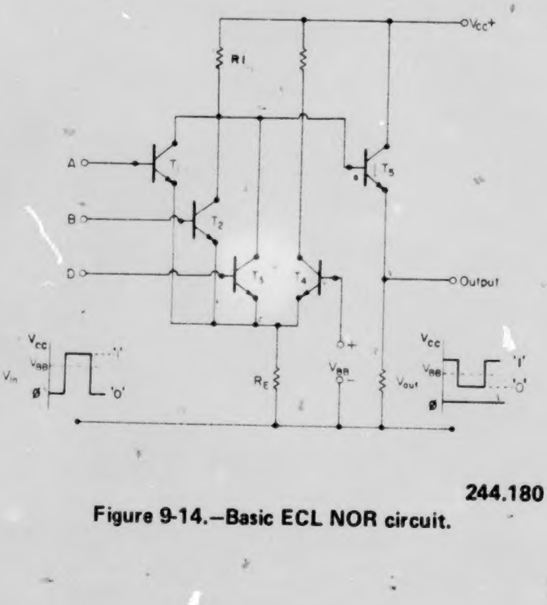

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Figure 9-14.–Basic ECL NOR circuit.

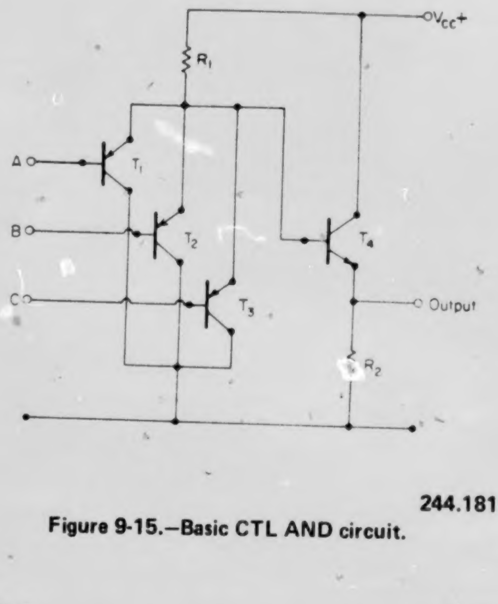

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Figure 9-15.–Basic CTL AND circuit.

Table 9-1.–Summary IC logic families

Family	Logic type	Relative cost per gate	Propagation time per gate, nanosec	Power dissipation per gate, mw	Typical noise margin, volts	Typical fan-in	Maximum fan-out
DCTL	NOR	Low	15	10	0.2	3	3
RTL	NOR	Medium	50	10	0.2	3	4
RCTL	NOR	Medium/high	30	10	0.2	3	4
DTL	NAND	Medium	25	15	0.7	8	8
TTL	NAND	Medium	10	20	1.0	8	12
ECL	OR/NOR	High	2	50	0.4	5	25
CTL	AND/OR	High	5	50	0.4	5	25
MOS	NOR	Very low	250	<1	2.5	10	5

* Values quoted are representative on a comparison basis. For any one family, the values may vary somewhat.

from transistor T4 (NPN) and the transistor conducts to give a positive output voltage, logical 1. If one of the inputs is reduced to ground potential, logical 0, the associated PNP transistor conducts, the current through R1 causes the common-emitter potential to fall, and the current through T4 falls giving a logical 0 output. As with the ECL circuit, the transistors do not go into saturation, and a fast switching speed is realized. The emitter-follower output gives a high fan-out capability, and the high input impedance allows easy coupling into the circuit.

SUMMARY IC LOGIC FAMILIES.–Table 9-1 summarizes the properties and features of the various integrated circuit logic families. Recall from *Digital Computer Basics*, NAVEDTRA 10088-A, DCTL is the simplest system, but it suffers from current hogging. This problem is somewhat alleviated in the RTL and RCTL circuits through the use of series resistors. All three systems have poor noise margins. DTL uses diodes for the logic, and has higher noise margins and faster switching. As noted earlier in this chapter, TTL uses a multiemitter transistor instead of diodes, and can switch faster with a high fan-out and good noise margin. ECL and CTL are nonsaturating circuits and have the highest speed and fan-out, but they also have the highest power consumption.

In the detailed design of each family of circuits, there is a compromise between switching speed and power dissipation, which allows variations depending upon the specific requirement for a circuit. Figure 9-16 shows the relationship between typical propagation time and power dissipation for the various integrated circuit logic families.

Troubleshooting

The following discussion on troubleshooting digital integrated circuits includes information concerning the fundamental differences between troubleshooting equipment containing discrete analog circuits and equipment containing digital integrated circuits. It also includes information concerning the failure modes of digital ICs, and the test equipment designed exclusively for digital troubleshooting.

ANALOG VERSUS DIGITAL.–When troubleshooting circuits built from analog components, the TD's task is one of verifying relatively simple characteristics such as resistance, capacitance, or turn-on voltages of components with two or, at most, three nodes.

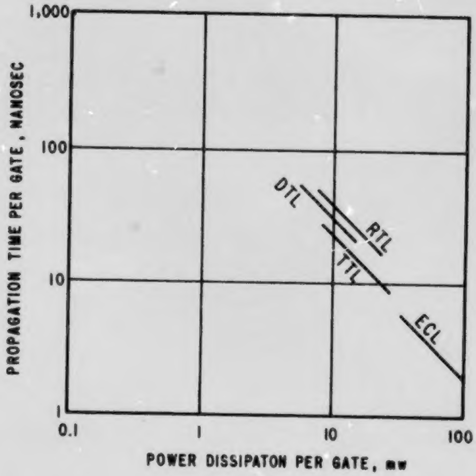

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Figure 9-16.—Propagation time versus power dissipation of logic IC circuits.

While the function of the total circuit might be quite complex, each component in that circuit performs a relatively simple task, and proper operation is easily verified. In figure 9-17, each diode, resistor, capacitor, and transistor can be tested using a signal generator and a voltmeter, ohmmeter, diode checker, or oscilloscope—the traditional troubleshooting tools. But when this circuit is built in integrated circuit form, these components are no longer accessible. It now becomes necessary to test the operation of the complete circuit function.

Thus, an important difference between discrete circuitry and today's circuits built from digital ICs is in the complexity of the functions performed by these new "components". Unlike the resistor, capacitor, diode, or transistor, which must be interconnected to form a circuit function, digital ICs perform complete, complex functions. Instead of observing simple characteristics, the TD must now observe complex digital signals and decide if these signals are correct according to the function the IC is meant to perform.

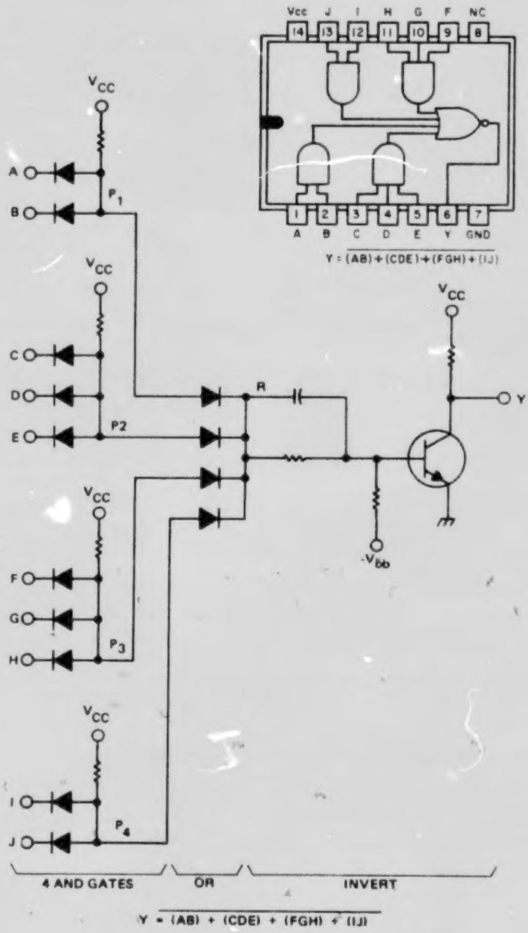

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Figure 9-17.—Discrete versus integrated circuits.

Verifying proper component operation now requires stimulating and observing many inputs (in figure 9-17 there are 10 inputs) while simultaneously observing several outputs (often 2 or 3 and, at times, as many as 8). Hence, another fundamental difference between circuitry built from discrete components and digital ICs is the number of inputs and outputs associated with each component and the need to stimulate and observe these simultaneously.

In order to solve these problems and make the troubleshooting of digital circuits more efficient, it is necessary to take advantage of the digital nature of the signals involved. Tools and techniques designed to troubleshoot analog

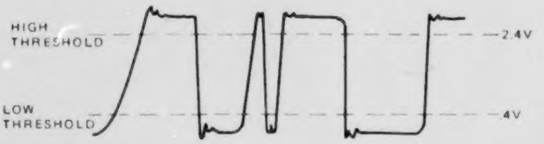

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Figure 9-18.–TTL signal.

circuits do not take advantage of this digital nature and in many cases, are less efficient.

Figure 9-18 shows a typical TTL signal. This might as well be any analog signal viewed on an oscilloscope. The oscilloscope displays absolute voltage with respect to time, but in the digital world, absolute values are unimportant. A digital signal exists in one of two or three states–high, low, and an undefined or in-between level, each determined by a threshold voltage. It is the relative value of the signal voltage with respect to these thresholds that determines the state of the digital signal, and this digital state, not the absolute levels, determines the operation of the IC. In figure 9-18, if the signal is greater than 2.4 volts, it is a high-state and is unimportant whether the level is 2.8 or 3.0 volts. Similarly, for a low state, the voltage must be below .4 volts. It is not important what the absolute level is as long as it is below this threshold. Thus, when using an oscilloscope, the TD must over and over again determine if the signal meets the threshold requirement for the desired digital state.

Within a digital logic family, such as TTL, the timing characteristics of each component are well defined. Each gate in the TTL logic family displays a characteristic propagation time, rise time, and fall time. The effects of these timing parameters on circuit operation are taken into account by the designer. Once a design has been developed beyond breadboard or prototype stage and is into production, problems due to design have usually been corrected. An important characteristic of digital ICs is when they fail, they fail catastrophically. This means the timing parameters rarely degrade or become marginal. Thus, observing signals on an oscilloscope and making repeated decisions on the validity of timing parameters is time consuming and contributes very little to the troubleshooting process. Once problems due to design are corrected, the fact that pulse activity exists is usually enough indication of proper IC operation.

Figure 9-19 shows a problem created by the TTL logic family. The output stage of a TTL device is a transistor totem pole. In either the high or low state, it is a low impedance. In the low state it is a saturated transistor to ground. It thus appears as 5-10 ohms to ground. This presents a problem to in-circuit stimulation. A signal source used to inject a pulse at a node which is driven by a TTL output must have sufficient power to override the low impedance output state. Most sources presently used for troubleshooting do not provide this capability. It has been necessary for the troubleshooter to either cut printed-circuit traces or pull IC leads in order to stimulate the circuit being tested. Both of these practices are time consuming and lead to unreliable repairs.

Thus, the use of the traditional oscilloscope and signal sources is inefficient. These tools are general purpose equipments that can be applied to any situation if the troubleshooter has enough time. But more importantly, the most efficient solution to the problem will be found in the proper utilization of the proper test equipment, i.e., oscilloscopes, diode checkers, voltmeters, etc., on analog circuits and digital

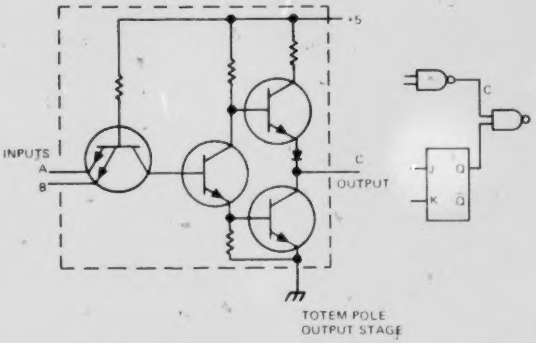

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Figure 9-19.–TTL logic output stage.

instruments (probes, pulsers, comparators, etc.) on digital circuits. These digital test equipments will be described in this chapter after a look at the failure modes of digital ICs.

FAILURE MODES.–In order to troubleshoot efficiently, it is important to understand the types of failures found in digital circuits. These can be categorized into two main classes–those caused by a failure internal to an IC, and those caused by a failure in the circuit external to the IC.

There are four types of failures that can occur internally to an IC. These are (1) an open bond on either an input or output, (2) a short between an input or output and V_{CC} or ground, (3) a short between two pins (neither of which are V_{CC} or ground), and (4) a failure in the internal circuitry (often called steering circuitry) of the IC.

In addition to these four failures internal to an IC, there are four failures that can occur in the circuit external to the IC. These are (1) a short between a node and V_{CC} or ground, (2) a short between two nodes (neither of which are V_{CC} or ground), (3) an open signal path, and (4) a failure of an analog component.

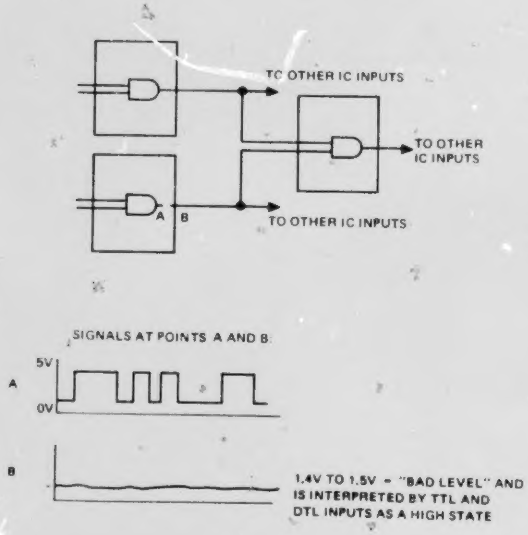
TO OTHER IC INPUTS
TO OTHER IC INPUTS
A
B
TO OTHER IC INPUTS
SIGNALS AT POINTS A AND B
5V
A
0V
B
1.4V TO 1.5V = "BAD LEVEL" AND IS INTERPRETED BY TTL AND DTL INPUTS AS A HIGH STATE

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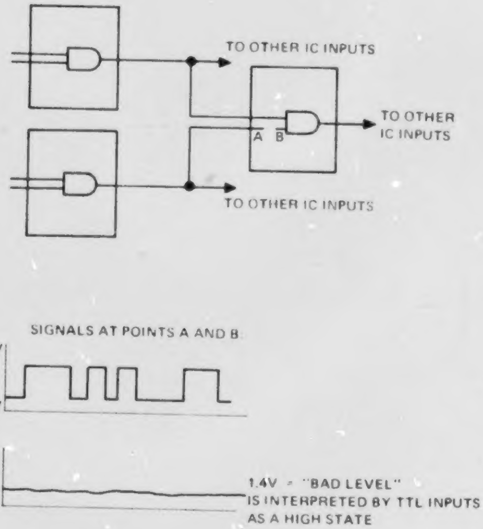
Figure 9-20.–Open output bond.


TO OTHER IC INPUTS
A
B
TO OTHER IC INPUTS
TO OTHER IC INPUTS
SIGNALS AT POINTS A AND B
5V
A
0V
5V
B
0V
1.4V = "BAD LEVEL" IS INTERPRETED BY TTL INPUTS AS A HIGH STATE

244.187

Figure 9-21.–Open input bond.

The first failure internal to an IC mentioned above was an open bond on either the input or output. This failure has a different effect on circuit operation depending upon where it occurs. In the case of an open output bond (fig. 9-20), the inputs driven by that output are left to float. In TTL and DTL circuits, a floating input rises to approximately 1.4 to 1.5 volts. Thus, an open output bond will cause all inputs driven by that output to float to a bad level since 1.5 volts is less than the high threshold level of 2.0 volts and greater than the low threshold level of .4 volt. In TTL and DTL, a floating input is interpreted as a high level. The effect will be that these inputs respond to this bad level as though it were a static high signal.

In the case of an open input bond (fig. 9-21), the open circuit blocks the signal driving the input and prevents it from entering the IC chip. The input on the chip is allowed to float and will respond as though it were a static high signal. It is important to realize that since the open occurs on the input inside the IC, the digital signal driving this input will be unaffected by the open and will be detectable when looking at the input pin (such as point A in figure 9-21).

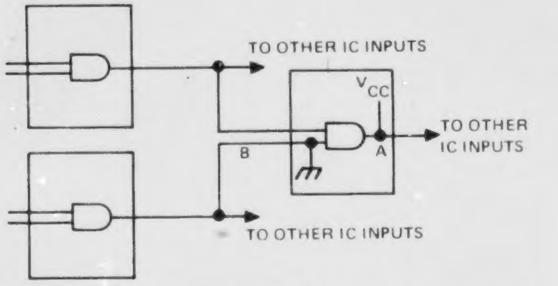


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Figure 9-22.–Shorted input or output.

The effect will be to block this signal inside the IC and the resulting IC operation will be as though the input were a static high.

A short between an input or output and V_{CC} or ground (fig. 9-22), has the effect of holding all signal lines connected to that input or output either high (in the case of a short to V_{CC}) or low (if shorted to ground). In many cases, this will cause expected signal activity at points beyond the short to disappear. This type of failure is catastrophic in terms of circuit operation.

A short between two pins is not as straightforward to analyze as the short to V_{CC} or ground (fig. 9-23). When two pins are shorted, the outputs driving those pins can oppose each other, e.g., when one signal attempts to pull the pins high, the other attempts to pull them low. In this situation the output attempting to go high will supply current through the upper saturated transistor of its totem pole output stage while the output attempting to go low will sink this current through the saturated lower transistor of its totem pole output stage. The net effect is that the short will be pulled to a low state by the saturated transistor to ground. Whenever both outputs attempt to go high simultaneously or to go low simultaneously, the shorted pins will respond properly.

The fourth failure internal to an IC is a failure of the internal "steering circuitry" of the

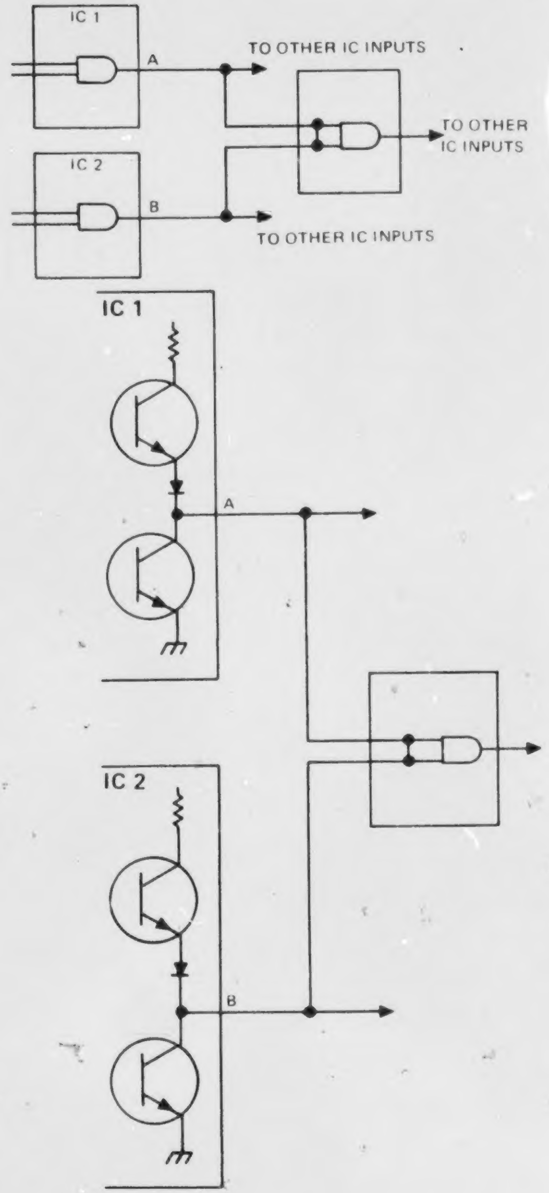

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Figure 9-23.–Shorted pins.

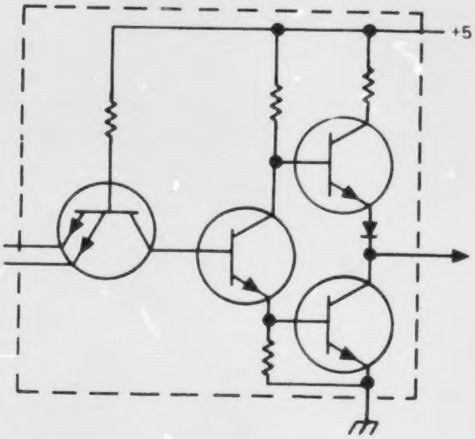

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Figure 9-24.—Steering circuitry failure.

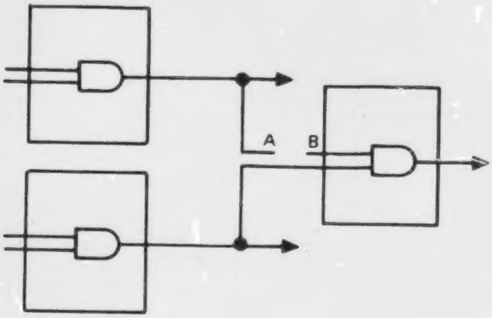

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Figure 9-25.—Open in external circuit.

IC (shaded area of figure 9-24). This has the effect of permanently turning on either the upper transistor of the output totem pole, locking the output in the high state, or turning on the lower transistor of the totem pole, locking the output in the low state. Thus, this failure blocks the signal flow and has a catastrophic effect upon circuit operation.

A short between a node and V_{CC} or ground external to the IC is indistinguishable from a short internal to the IC. Both will cause the signal lines connected to the node to be either always high (for shorts to V_{CC}) or always low (for shorts to ground). When this type of failure is encountered, only a very close physical examination of the circuit will reveal if the failure is external to the IC.

An open signal path in the circuit has a similar effect as an open output bond driving the node (fig. 9-25). All inputs to the right of the open will be allowed to float to a bad level and will appear as a static high level in circuit operation. Those inputs to the left of the open will be unaffected and will respond as expected.

DIGITAL TEST EQUIPMENT.—Inaccessibility of discrete components, complexity of functions, and the number of components requiring simultaneous stimulation and observation were, as described above, three factors which brought about the need for a new breed of test equipment. Manufacturers of test equipment have responded with a series of testers that include logic probes, logic pulsers, test clips, comparators, and logic analyzers.

Logic analyzers are test instruments with the display, triggering, and delayed sweep features of an oscilloscope, but tailored to the demands of the digital environment. They fall into three categories: state analyzers, timing analyzers, and trigger generators.

State analyzers display digital data in the form of 1's and 0's on a cathode-ray tube or via light-emitting diodes, in a word-versus-event format. This concentration on word sequences makes state analyzers useful in examining the functional behavior of binary systems, e.g., the flow of command and data words on multiline buses.

A logic-timing analyzer is more like an oscilloscope; it displays digital data in a word-versus-time format, or reconstructs the original waveform and displays it in a pseudo voltage-versus-time mode. Such displays are somewhat more difficult to interpret than 1's and 0's but offer information which can be helpful in examining the functional behavior of the digital system. Timing analyzers usually include the capability to display glitches, rise times, and pulse ringing.

Logic-trigger generators are simpler devices and are designed for use with oscilloscopes. They may be as simple as a four-input AND gate connected to a scope trigger input to synchronize the scope with the occurrence of a particular four-bit parallel word. They may contain digital counters to delay triggering by a set number of events, or shift-register comparators to allow recognition of serial words for triggering.

Logic probes (fig. 9-26 (A)) are test probes designed to simplify logic testing by giving the user a direct readout of logic levels without the set-up and calibration time needed by logic analyzers and scopes. They use one or more lamps to indicate whether a point in a digital signal path is at a logic 1, a logic 0, or is toggling between those levels. The Hewlett-Packard probes use a single lamp (arrow points to translucent ring near probe tip)—on for 1, off for 0, and blinking at a 10-Hz rate for toggling. A constant half-brightness indicates no signal is present.

To make the most of logic probes requires some means of changing the state of gate inputs while examining the gate's output. Logic pulsers (fig. 9-26 (B)) are designed to perform this function. Logic pulsers briefly drive circuit nodes to the logic state opposite their present states. Pulse widths are usually tenths of a microsecond—short enough to prevent destroying the logic under test.

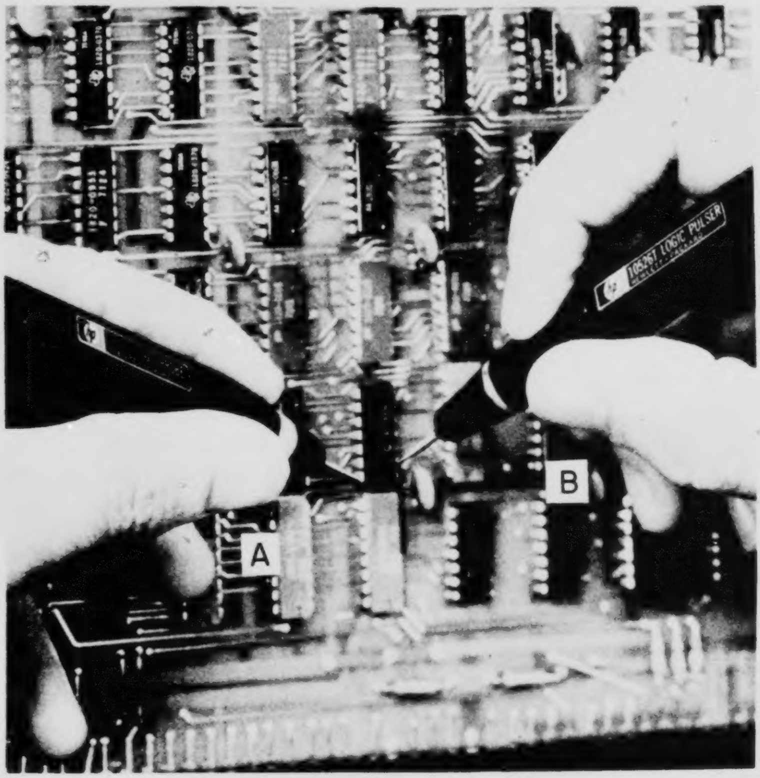

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Figure 9-26.—Logic probe and pulser.

While stimulus-response testing is the mainstay of electronic troubleshooting, the digital nature of the signals of the circuit being tested allows for an even faster means of verifying proper component operation. By stimulating a known good device with the same signals used to stimulate the device under test, and comparing the responses of the two components, it can be verified whether or not the device under test is operating properly. This is exactly what the LOGIC COMPARATOR does, (fig. 9-27). It connects the test and reference IC inputs in parallel, so the reference IC and the test IC are exercised by the same signals. Any differences in the outputs are detected and displayed, usually by an LED lamp corresponding to the failed pin. Applications of these test equipments will be discussed in a digital troubleshooting algorithm after an introduction to systems troubleshooting.

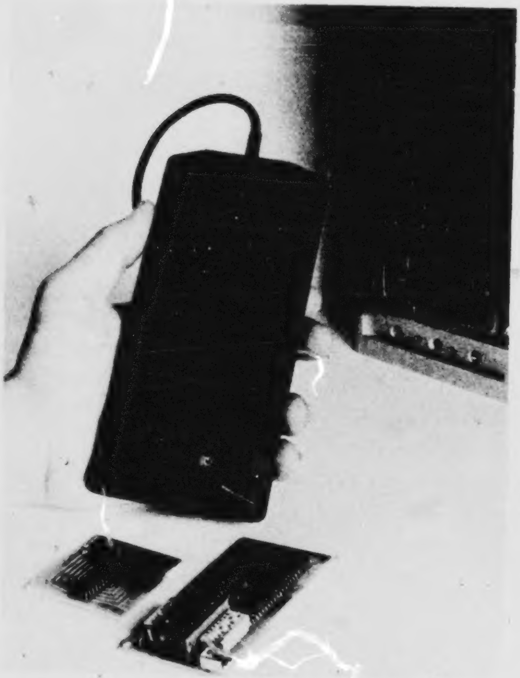

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Figure 9-27.—Logic comparator.

DIGITAL SYSTEMS TROUBLESHOOTING

Troubleshooting digital simulator systems require a familiarization with the basic techniques used in computer/interface/training vehicle and training vehicle/interface/computer communications. These techniques were discussed in the previous chapter and are now briefly reviewed. (1) The training vehicles supply, via the interface equipment, digital and analog inputs to the computer, which indicate the position of switches and potentiometers, respectively. The computer uses these inputs as data in a program that will compute the appropriate data for output actions and responses. (2) The computer supplies, via the interface equipment, digital and analog outputs to the training vehicles that control instruments and indicators.

With a detailed knowledge of how a system works, the first step in troubleshooting a malfunctioning system is problem analyzation.

PROBLEM ANALYZATION

The analyzation of a problem can be as simple as the observation of a visual indicator failing (bulb burning out), to as complex a problem as that generated by the failure of computer or interface timing. Whatever the complexity of the malfunction, a systematic approach to trouble analysis will provide for the optimum isolation of defective components.

In normal troubleshooting, the presence of a malfunction will normally be indicated by the operator or it may become apparent while running the morning readiness checks. (The morning readiness checks are a series of programs that provide confidence tests for the major components of the simulator system.) Once it has been ascertained that a malfunction does exist (more than one manhour has been wasted troubleshooting a nonexistent trouble), the problem should be localized to a major section.

Localization

When you begin to localize a malfunction, the first check is for proper output from the power supplies. Since they affect all electronic circuits in the simulator system, erroneous clues as to the actual problem can be picked up if you rely entirely on an observation of training vehicle performance.

Once the power supplies have been eliminated as the problem area, the performance of the training vehicle is observed and logical reasoning is used to determine what major section (computer, interface, training vehicle) or input/output communication signal (analog or digital) is failing.

Computer

Malfunctions can be localized to the computer (or at least it becomes suspect) if any of the following observations are made:

1. Parity errors occur

2. Computer intermittently halts or stops at odd memory locations

3. Performs instructions out of the normal range of the program being run

4. Provides incorrect data to output devices

5. Will not read, or reads incorrectly, from input devices

If in fact the computer exhibits any of the above symptoms, it should be tested in depth using the standard test programs provided by the computer manufacturer. This set of programs include, but is not limited to, CPU tests, MEMORY tests, and I/O tests. These test programs can be used to further isolate the problem. Isolation techniques are discussed in depth later in this chapter.

Interface/Training Vehicle

Localizing the problem to a major subsection is accomplished by observing the performance of the training vehicle and then using logical reasoning as to the type of input and/or output that is failing. Localization can be accomplished best by the process of elimination, until one section or unit in the interface/training vehicle is suspected.

The following hints will assist the technician in this localization phase of troubleshooting.

1. If all inputs and outputs are failing, the problem probably lies in the timing circuits, because signals from these circuits are employed throughout the interface system.

2. If all the analog inputs are working but all analog outputs are failing, the D/A converter is probably the faulty device.

3. The malfunction of a single analog output device would point to a sample/hold card or possibly a gate feeding that particular sample/hold card.

4. A built-in troubleshooting aid is provided by simulators having multiple trainee stations. A properly operating trainee station will provide a standard against which the malfunctioning station can be compared.

PROBLEM ISOLATION

Once the problem has been analyzed and localized to a particular subsection, the next step is problem/fault isolation. Isolation as used here simple means tracing the malfunction to one or more failing components. Some malfunctions, such as binding mechanical parts, defective cabling or wiring, loose components, etc, can be isolated by sight, touch, or hearing (sensory tests). As mentioned in the section on problem analyzation, a check of power supply outputs will often prove to be a short-cut to the problem. The majority of faults, however, must be isolated by executing programmed diagnostics and/or signal tracing. Table 9-2 contrasts these two methods.

Signal Tracing

Signal tracing is most often initiated by specific fault information, e.g., digital output to depth indicator is failing. Controlled, compatible information signals are a prerequisite, and most of the new devices being built have a program that provides these signals. Those devices that do not have these programs must be programmed by the TD technician.

Table 9-2.—Contrasting maintenance concepts

SIGNAL TRACING	DIAGNOSTIC ROUTINES
On-line and off-line	Off-line
Manual	Automatic
Queried	Control requested
Slow checkout	Rapid checkout
Flexible attack	Rigid constraints
Empirical analysis	Theoretical analysis
Skilled technique	TTY/flexowriter manipulated
Unique personnel	Unique/softwares
Doubtful QC	Hard-copy QC
Precise results	Approximate results
Final	Intermediate

The experienced technician can utilize the terminals to efficiently generate and inspect all the analog/discrete conditions. Faulty information signal channels are then manually probed with conventional test equipment. Signal tracing under controlled signal conditions can isolate the trouble to the failing specific component or module.

Diagnostic Routines

As noted in Table 9-2, the diagnostic routines are operated with the trainer off-line. The technician manipulates the system with some type of terminal, e.g., teletypewriter (TTY), flexowriter, etc. The computer then reports system status via the same terminal. Based on this response, substitution maintenance is performed at the circuit assembly level and the actual troubleshooting/repair of the card/circuit assembly is performed on a card tester or test bench.

There is a wide variance between the levels of the diagnostics found on various digital simulators. Device 2F101 (T2C) has a closed-loop test mode that enables automated diagnostics under control of the PDP 11-45 computer. This "closed-loop" is formed in the interface unit by wrapping around the I/O signals via a set of relays. Other devices use a simple modification of the main trainer program to stimulate the various output devices while the technician observes their performance. Whatever the complexity of the diagnostic routine, it will be device-dependent and described in the maintenance handbook.

Digital Troubleshooting Algorithm

Once the problem has been isolated to a single circuit, the digital test equipment (logic probe, pulser, comparator, etc.) discussed earlier can be used to observe the effect of the failure on circuit operation and locate the cause of the failure (either an IC or a fault in the circuit external to the IC). The algorithm listed in Table 9-3 and described below provides significant improvements over conventional troubleshooting techniques/equipments by providing a digital solution to the digital troubleshooting problem.

With today's training devices containing hundreds of ICs, the problem of troubleshooting becomes one of physically isolating the trouble to the two or three ICs affected by the failure. A majority of today's troubleshooting time is spent looking at signals which are good, and determining that they are good. This is time spent getting to the problem, not solving the problem. A logic comparator can drastically reduce this time and quickly isolate the failure to only a few nodes out of the hundreds that exist on a digital circuit.

STEP 1.—The first step in the troubleshooting algorithm (Table 9-3) is to use the logic comparator to test all testable ICs (See the operator's manual for the comparator you are using.) in the circuit or portion of the circuit which is suspected of failing, and to note the ICs and pins the comparator indicates as failing. Note: A sensitive logic comparator will often indicate a failure because its clip is not making good contact, especially when the ICs have been

Table 9-3.–Digital troubleshooting algorithm

STEP 1.	Test all ICs using logic comparator or logic probe, pulser, and clip and note the failing nodes. (Steps 2 through 5 should be repeated for each failing node noted in step 1.)
STEP 2.	Test for an open output bond driving the failing node using the logic probe.
STEP 3.	Test for a short to V_{CC} or ground using the logic probe and pulser.
STEP 4.	Test for a short between two nodes using the logic probe and pulser or an ohmmeter.
STEP 5.	If the failure is not found in steps 2 through 4, then the failure is either an open input bond or a failure of the internal circuitry of the IC driving the failing node.

sprayed with a sealer. Thus, before deciding that a node definitely does not compare, squeeze the clip's jaws tightly and apply a slight twisting motion.

The logic probe, pulser, and clip can be used to verify proper IC operation for those ICs that are not testable with the logic comparator. The logic probe can be used to observe the signal activity on inputs and to view the resulting output signals. From this information, a decision can be made as to the proper operation of the IC. For example, if a clock signal is occurring on a decade counter and the enabling inputs (usually reset lines) are in the enabled state, then the output should be counting. The logic probe will allow the clock and enabling inputs to be observed, and, if pulse activity is indicated on the outputs, then the IC can be assumed to be operating properly. As stated before, usually it is not necessary to see the actual timing of the output signals since ICs fail catastrophically. The occurrence of pulse activity is often enough indication of proper operation.

When more detailed study is desired or when input signal activity is missing, the logic pulser can be used to inject input signals and the logic clip or probe used to monitor the response. This technique is especially good when testing digital gates and other combinatorial devices. The logic pulser can be used to cause the inputs to go to a state which will cause a change in the output state. For example, a three-input NAND gate which has high, low, low inputs will have a high output. By pulsing the two low inputs high using a logic pulser (and a multipin stimulus attachment, if necessary), the output will pulse low and can be detected by the logic probe. This then indicates the IC is operating properly. The logic pulser is also valuable for replacing the clock in a digital circuit, thus, allowing the circuit to be single-stepped while a logic probe or clip is used to observe changes in the circuit's state.

This first step might be called the "mapping" step since the effect is to map out the problem areas for further investigation. It is important to do a complete "mapping" of the circuit before proceeding to analyze each of the indicated failures. Prematurely studying a fault can result in overlooking faults which cause multiple failures, such as shorts between two nodes. This then often leads to the needless replacement of a good IC and much wasted time. With a complete trouble-area "map", we can begin to determine the type and cause of the failures. We do this by systematically eliminating the possible failures of digital circuits discussed above.

STEP 2.–The first failure to test for is an open bond in the IC driving the failed node. The logic probe provides a quick and accurate test for this failure. If the output bond is open, then the node will float to a bad level. By probing the node, the logic probe will quickly indicate a bad level. If a bad level is indicated, the IC driving the node should be replaced and retested with a logic comparator.

STEP 3.–If the node is not a bad level, a test for a short to V_{CC} or ground should be made next. This can be done easily using a logic pulser and probe. While a logic pulser is powerful enough to override even a low impedance TTL output, it is not powerful enough to effect a change in state on a V_{CC} or ground bus. Thus, if a logic pulser is used to inject a pulse, while a logic probe is used simultaneously on the same node to observe the pulse, a short to V_{CC} or ground can be detected. The occurrence of a pulse indicates the node is not shorted, and the absence of a pulse indicates the node is shorted to V_{CC} (if it is a high) or ground (if it is a low).

If the node is shorted to V_{CC} or ground, there are two possible causes. The first is a short in the circuit external to the ICs, and the other is a short internal to one of the ICs attached to the node. The external short should be detected by an examination of the circuit. If no external short is found, then the cause is equally likely to be any one of the ICs attached to the node. The only suggestion that can be made (based upon experience) is to first replace the IC driving the node, and if that does not solve the problem, try each of the other ICs individually until the short is eliminated. (It might be noted that on occasion analog components attached to the node such as resistors or capacitors have shorted.)

STEP 4.–If the node is not shorted to V_{CC} or ground, nor is it an open output bond, the technician should look for a short between two nodes. This can be done in one of two ways. First a logic pulser can be used to pulse the failing node being studied and a logic probe can be used to observe each of the remaining failing nodes. If a short exists between the node being studied and one of the other failing nodes, then a pulser will cause the node being probed to change state (i.e., the probe will detect a pulse). To ensure that a short exists, the probe and pulser should be reversed and the test made again. If a pulse is again detected, a short is definitely indicated. As a further test or as another way of testing for a short between two nodes, the circuit can be removed from the instrument or system and an ohmmeter used to measure the impedance between the two failing nodes. A short between them will be easily detected.

If the failure is a short, there are two possible causes. The most likely is a problem in the circuit external to the ICs. This can be detected by physically examining the circuit and repairing any solder bridges or loose wire shorts found. Only if the two shorted nodes are common to one IC, can the failure be internal to that IC. If after examining the circuit no short can be found external to the IC, then the IC should be replaced.

STEP 5.–If the failure is not a short between two nodes, there are only two possibilities left–(1) the failure is an open input bond, or (2) a failure of the internal circuitry of the IC that the comparator indicates has failed. In either case, this IC should now be replaced. Thus, by systematically eliminating the IC failures, the cause can be located.

An important step at any point where an IC is replaced is the retesting of the circuit. If the test again indicates a failure, then more study of the problem must be made with the knowledge that the failure is not in the IC that has just been replaced.

There is one type of failure that was not discussed in the algorithm, and that is an open signal path in the circuit external to the IC (Fig. 9-28). This type of failure will not be indicated by a logic comparator and will therefore not be shown on the trouble-area map. If after using

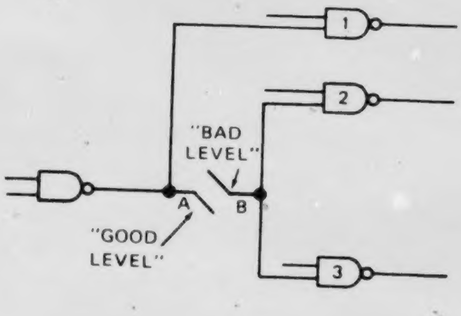

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Figure 9-28.–Open signal path external to ICs.

the logic comparator to test all the ICs, no nodes are indicated as failing, or, if after finding the cause of the failures indicated by the logic comparator, the circuit is still malfunctioning, then an open signal path can be suspected.

The logic probe provides a rapid means of not only detecting but also physically locating the open. Since an open signal path allows the input to the "right" of the open to float to a bad level, the logic probe can be used to test the input of each IC for a bad level. Once an input floating at a bad level is detected, the logic probe can be used to follow the circuit back from the input looking for the open. This can be done because the circuit to the "left" of the open will be a good logic level (either high, low, or pulsing) while the circuit to the right will be a bad level. Thus, probing back along the signal path will indicate a bad level until the open is passed. Thus, the probe can be used to locate precisely the open. The open can then be repaired and the circuit tested.

This systematic elimination of possible failures in digital circuits coupled with proper use of digital IC test equipment will ensure a rapid and accurate repair. Because this equipment provides a digital solution to the digital problem, improvements in troubleshooting time of 4 to 1 are claimed by one manufacturer of test equipment.

APPENDIX I

GENERAL PURPOSE DIGITAL COMPUTERS INCORPORATED IN COG '20' TRAINING EQUIPMENT

DEVICE NUMBER	DEVICE TITLE	COMPUTERS	LOCATION
1A22	Operational Nav Trnr	DDP-116	NAS, Corpus Christi, TX
1D23	Comm and Nav Trnr	NOVA 800 PDP8/E	NAS, Pensacola, FL
2B10A	SH-3A Helicopter Instr Trnr	DDP-24	NSC, Norfolk, VA NAS, North Island, San Diego, CA MCAS, Futema, Okinawa
2B18	THIL Basic Hlcpter Instr Trnr	SEL-811	NAS, Whiting Field, Milton, FL
2B21	Instrument Flt Basic Trnr	DDP-124	NAS, Whiting Field, Milton, FL NATTC, Millington, TN
2B35	CGI Visual System	PDP-11/45	NAS, Chase Field, Beeville, TX
2C20A	E2C CPT	H316	FASOTRAGRULANT, Norfolk, VA
2D2	Electronic Warfare Range	DDP-516 UNIVAC 1230 AN/UYK-7	NAS, Fallon, NV NAS, Jacksonville, FL
2F64A	SH-3A Weapons Sys Trnr	DDP-24	FASOTRAGRUPAC, Imperial Beach, CA

Appendix I—GENERAL PURPOSE DIGITAL COMPUTERS INCORPORATED IN COG '20' TRAINING EQUIPMENT

DEVICE NUMBER	DEVICE TITLE	COMPUTERS	LOCATION
2F64B	SH-3D Weapons Sys Trnr	DDP-24	FASOTRAGRULANT, Jacksonville, FL
			FASOTRAGRUPAC, Imperial Beach, CA
2F65	E-2B Acft WST	UNIVAC 1230	FASOTRAGRUPAC, San Diego, CA
2F66A	S-2E Acft WST	PB250	NARU, NAS, North Island, San Diego, CA
			FASOTRAGRULANT, Cecil Field, FL
2F66D	S-2D WST	PB250 H316	FASOTRAGRULANT, Cecil Field, FL
2F67	A-6A Acft WST	CP-642A	MCAS, Cherry Pt, NC
2F67A	A-6A Acft WST	CP-642A	FASOTRAGRUPAC, Whidbey Island, Oak Harbor, WA
2F67B	A-6A WST	CP-642A	FASOTRAGRULANT Oceana, Virginia Beach, VA
2F67C	A-6A WST	UNIVAC 1230	FASOTRAGRUPAC, Whidbey Island, Oak Harbor, WA
2F69D	P-3A WST	DDP-516	FASOTRAGRULANT, Brunswick, ME
			FASOTRAGRUPAC, Moffett Field, CA
			FASOTRAGRULANT, Patuxent River, MD
			FASOTRAGRUPAC, Barbers Point, Oahu, HI
2F78	RA-5C Acft WST	PDP 11/15	FASOTRAGRULANT, Key West, FL

DEVICE NUMBER	DEVICE TITLE	COMPUTERS	LOCATION
2F84	A-7A WST	DDP-224 GP4	FASOTRAGRULANT, Cecil Field, FL
			FASOTRAGRUPAC, Lemoore, CA
2F84B	A-7E WST	DDP-224 GP4	FASOTRAGRULANT, Cecil Field, FL
			FASOTRAGRUPAC, Lemoore, CA
2F87(T)	P-3C Tactics WST	DDP-516	FASOTRAGRULANT, Jacksonville, FL
			FASOTRAGRULANT, Det Pax River, MD
			FASOTRAGRUPAC, Det Moffett, Moffett Field, CA
2F87A(T)	P-3C Tactics WST	DDP-516	NAS, Moffett Field, CA
2F87(F)	P-3C OFT	PDP-11/45	NAS, Moffett Field, CA
2F88	F-4J WST	GP4B	FASOTRAGRUPAC, Miramar, San Diego, CA
			FASOTRAGRULANT, Oceana, Virginia Bch, VA
			MCAS, Yuma, AZ
2F90	TA-4J Acft OFT	SIGMA 5	NAS, Kingsville, TX
			NAS, Pensacola, FL
			NAS, Chase Field, Beeville, TX
			NAS, Meridian, MS
			NAS, Oceana, Virginia Bch, VA

Appendix I–GENERAL PURPOSE DIGITAL COMPUTERS INCORPORATED IN COG '20' TRAINING EQUIPMENT

DEVICE NUMBER	DEVICE TITLE	COMPUTERS	LOCATION
2F90 Visual	TA-4J Acft OFT Visual Attach	SEL 840A	NAS, Kingsville, TX
2F92	S-3A WST	PDP 11/45	NAS, North Island, San Diego, CA
			NAS, Quonset Point, RI
2F95	F-14A OFT	SIGMA 5	FASOTRAGRUPAC, Miramar, San Diego, CA
			NAS, Miramar, San Diego, CA
			NAS, Oceana, Virginia Beach, VA
2F99	AV-SA OFT	SIGMA 3	MCAS, Cherry Pt., NC
2F101	T-2C OFT	PDP 11/45	NAS, Chase Field, Beeville, TX
			NAS, Kingsville, TX
			NAS, Meridian, MS
			NAS, Pensacola, FL
2F103	A7E Night Carrier Landing Trnr	DC 6024/1	FASOTRAGRUPAC, Lemoore, CA
			FASOTRAGRULANT, Cecil Field, FL
2F106	SH-2F Helicopter WST	DC 6024/5	NAS, Norfolk, VA
			NAS, Imperial Bch, CA
2F107	KC-130F OFT	PDP 11/45	MCAS, El Toro, CA
2F108	A-UM OFT NCLT	DC 6024/5	MCAS, Yuma, AZ
			MCAS, Beaufort, SC

DEVICE NUMBER	DEVICE TITLE	COMPUTERS	LOCATION
2F111	A-7E WST	DC 6024/1	NAS, Lemoore, CA NAS, Cecil Field, FL
6F7	DDP-24 G.P. Dig Comp Maint Trnr	DDP-24	NAVTRAEQUIPCEN, Orlando, FL
6F9	MICRO-810 Dig Comp Maint Trnr	MICRO-810	NATTC, NAS Memphis, Millington, TN
6F15	Dig Maint Trnr	DDP-516	NAVTRAEQUIPCEN, Orlando, FL
7B1/1	Simulator Electro-Magnetic	HP 2100A	NAVSUBSCOL, Groton, CT NAVSUBTRACENPAC, Pearl Harbor, HI
8A10	Morse Code Trnr MCT-4	DDP-516	NAVCOMMTRACEN, Pensacola, FL
10A3/2	EW Oper Trnr	HP 2100A	NAVSCOLCOM, Treasure Island, San Fran, CA
14A2A	Surface Ship ASW Attack Trnr	XDS-930	FLEASWTRACENPAC, San Diego, CA
14A2B	Surface Ship ASW Attack Trnr	XDS-930	NAVOFFTRACEN, Newport, RI
14A2C/1	Surface Ship ASW Attack Trnr	XDS-930	FLESONARSCOL, Key West, FL
14A2D	Surface Ship ASW Attack Trnr	XDS-930	FLEMINEWARTRACEN, Charleston, SC
14A2E	Surface Ship ASW Attack Trnr	XDS-930	FLEASWTRACENPAC, San Diego, CA
14A2F	Surface Ship ASW Attack Trnr	XDS-930	COMFLETRAGRU Pearl Harbor, HI
14A2G	Surface Ship ASW Attack Trnr	XDS-930	LANTFLEASWTACSCOL, Norfolk, VA

Appendix I–GENERAL PURPOSE DIGITAL COMPUTERS INCORPORATED IN COG '20' TRAINING EQUIPMENT

DEVICE NUMBER	DEVICE TITLE	COMPUTERS	LOCATION
14B40	Universal Radar/MAD Trnr ASW Attack Trnr	DDP-516	FASOTRAGRULANT, Patuxent River, MD FASOTRAGRUPAC, Moffett Field, CA
14B44	P-3C Acft DIFAR Oper Trnr	DDP-516	FASOTRAGRULANT, Patuxent River, MD FASOTRAGRUPAC, Moffett Field, CA FASOTRAGRULANT, Jacksonville, FL NAS, Barbers Point, HI
14B49	P-3C Acft DIFAR Oper Trnr	PDP 11/45	NAS, North Island, San Diego, CA
14E19	SQS-26CX Basic Oper/Team Trnr	DDP-516	FLEASWSCOL, San Diego, CA NAVTRASUPPDET, NORVA, Norfolk, VA FLEMINEWARTRACEN, Charleston, SC NAVOFFTRACEN, Newport, RI COMFLETRAGRU, Pearl Harbor, HI LANTFLEASWTACSCOL, Norfolk, VA
14E23	AN/SQQ-35 IVD Sonar Oper Trnr	H-716	FLEASWSCOL, San Diego, CA FASOTRAGRULANT, Norfolk, VA
14E24	AN/SQQ-23 (PAIR) Sonar Oper Trnr	H-716	FLEASWSCOL, San Diego, CA FLEMINEWARTRACEN, Charleston, SC

DEVICE NUMBER	DEVICE TITLE	COMPUTERS	LOCATION
14E25	AN/SQS-53/26CX Sonar Oper Trnr	DDP-516 H-716	FLEASWSCOL, San Diego, CA
15C9	F-14A Missile Control Officer Trnr	SIGMA 5 CDC 5400C	FASOTRAGRUPAC, Miramar, San Diego, CA
15C9A	F-14A Missile Control Officer Trnr	SIGMA 5 CDC 5400C	NAS, Oceana, Virginia Beach, VA FASOTRAGRUPAC, Miramar, San Diego, CA
15E18	ECM Elec Countermeasures Trnr	CP-642B	NATTC, NAS, Glynco, GA FASOTRAGRUPAC, San Diego, CA
15E22	EA-6B Tactics Trnr	SEL-86 620 I	NAS, Whidbey Is, Oak Harbor, WA
15F5	E-2A Acft Tactics Trnr	CP-642A	NATTC, NAS, Glynco, GA
15F6	CIC Tactics Trainer	UNIVAC 1230	NATTC, NAS, Glynco, GA
15F8	E-2C Tactics Trnr	SEL 86 RAY 704	NAS, Norfolk, VA
15G13	Carrier Air Traffic Control Ctr, Trnr	CP-642A CP-642B	NATTC, NAS, Glynco, GA
15G17	Carrier Air Traffic Control Ctr, Trnr SPN-42	SUPER NOVA	FLTCOMBATDIRSYSTRACEN Pacific, San Diego, CA
15G17A	Carrier Air Traffic Control Ctr, Trnr NTDS/SPN-42	SUPER NOVA	FLTCOMBATDIRSYSTRACEN, Atlantic, Dam Neck, Virginia Bch, VA
15G19	GCA Oper Lab Trnr	NOVA 1220 NOVA 1210 DC 6024/5	NATTC, NAS, Glynco, GA

Appendix I—GENERAL PURPOSE DIGITAL COMPUTERS INCORPORATED IN COG '20' TRAINING EQUIPMENT

DEVICE NUMBER	DEVICE TITLE	COMPUTERS	LOCATION
16C53A	Amphibious SPTG Arms Evaluator	H316	NAVPHIBSCOL, Little Creek, Norfolk, VA
16C54	Amphibious SPTG Arms Evaluator	H316	NAVPHIBSCOL, Coronado, San Diego, CA
19E3	Central Control Oper Station	PDP 11/45	NTC, Great Lakes, IL
20A61	Maneuvering Tactics Trnr	UNIVAC 1230	NAVOFFTRACEN, Newport, RI
20A62	Shiphandling Emergency Trnr	SEL 810A	FLETRACEN, San Diego, CA
21A37	Sub FBM Training Facility	H-800 DDP-416 H316	NAVSUBSCOL, Groton, CT
21A38	ASW Submarine Training Facility	CDC 3100 CDC 1604B	NAVSUBTRACENPAC, Pearl Harbor, HI
21A39	SSBN 616 Class, Sonar Trnr	DDP-516 H-800	FLEBALMISSUBTRACEN, Charleston, SC
21A40	Submarine ASW Trnr	AN/UYK-7 UNIVAC 9300	NAVSUBTRACEN, PACDET, San Diego, CA
21B20B	Advanced Submerged Cont, Flasher/ Trigger Trnr	DDP-124	NAVSUBSCOL, Groton, CT
21B56C	Ship Basic High Speed Control Trnr	DDP-124	NAVSUBSCOL, Groton, CT
21B56D	Ship Basic High Speed Control Trnr	DDP-124	NAVSUBSCOL, Groton, CT
21B63	SSN 688 Gen Ind Fire Contr Opr Trnr	AN/UYK-7	NAVSUBSCOL, Groton, CT
21C5	Submarine Adv Submerged Contr Trnr	DDP-124	NAVSUBTRACEN, Pearl Harbor, HI

DEVICE NUMBER	DEVICE TITLE	COMPUTERS	LOCATION
21C7	Mult Cls Adv Sub Ship Cont Trnr	H316	NAVSUBSCOL, Groton, CT FLEBALMISSUBTRACEN, Charleston, SC NAVSUBSCOL DET Norfolk, VA NAVSUBTRACEN, PACDET, San Diego, CA
21C8	Trieste II Simulator	PB250	Deep Submergence School, San Diego, CA
21C9	DSRV Simulator	XDS-930	Deep Submergence School, San Diego, CA

NOTE: The following is a manufacturer to computer model cross reference list.

MANUFACTURER	COMPUTER CODES
Honeywell	H, DDP
Control Data Corp.	CDC
Raytheon	PB, RAY
Sperry	UNIVAC, CP, UYK
Xerox Data Systems	XDS, SIGMA
Data General	NOVA
Digital Equip. Corp.	PDP
Hewlett Packard	HP
General Precision	GP
MicroSystems	MICRO
Systems Engr. Lab	SEL
Varidan Data	I
Data Craft	DC

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TRADEVMAN 1 & C

NAVEDTRA 10378-D

Prepared by the Naval Education and Training Program Development
Center, Pensacola, Florida

Your NRCC contains a set of assignments and self-scoring answer sheets (packaged separately). The Rate Training Manual, TRADEVMAN 1&C, NAVEDTRA 10378-D, is your textbook for the NRCC. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the textbook or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

Study the textbook pages given at the beginning of each assignment before trying to answer the items. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. Also, read the learning objectives that precede the sets of items. The learning objectives and items are based on the subject matter or study material in the textbook. The objectives tell you what you should be able to do by studying assigned textual material and answering the items.

At this point you should be ready to answer the items in the assignment. Read each item carefully. Select the BEST ANSWER for each item, consulting your textbook when necessary. Be sure to select the BEST ANSWER from the subject matter in the textbook. You may discuss difficult points in the course with others. However, the answer you select must be your own. Use only the self-scoring answer sheet designated for your assignment. Follow the scoring directions given on the answer sheet itself and elsewhere in this course.

Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course you can complete it successfully by earning grades that average 3.2 or higher. If you are on active duty, the average of your grades in all assignments must be at least 3.2. If you are NOT on active duty, the average of your grades in all assignments of each creditable unit must be at least 3.2. The unit breakdown of the course, if any, is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed self-scoring answer sheet to the officer designated to administer it. He will check the accuracy of your score and discuss with you the items that you do not understand. You may wish to record your score on the assignment itself since the self-scoring answer sheet is not returned.

If you are completing this NRCC to become eligible to take the fleetwide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make a note in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed self-scoring answer sheet until you finish all the assignments in a unit (or in the course if it is not divided into units). Using the envelopes provided, mail your self-scored answer sheets to the Naval Education and Training Program Development Center where the scores will be verified and recorded. Make sure all blanks at the top of each answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. You may wish to record your scores on the assignments since the self-scoring answer sheets are not returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course (or a creditable unit of the course). To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the textbook and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the textbook and assignments are given on the book-return form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

Your examination for advancement is based on the Manual of Navy Enlisted Manpower and Personnel Classification and Occupational Standards (NAVPERS 18068-D). The sources of questions in this examination are given in the Bibliography for Advancement Study (NAVEDTRA 10052). Since your NRCC and textbook are among the sources listed in this bibliography, be sure to study both in preparing to take your advancement examination. The standards for your rating may have changed since your course and textbook were printed, so refer to the latest editions of NAVPERS 18068-D and NAVEDTRA 10052.

NAVAL RESERVE RETIREMENT CREDIT

This course is evaluated at 12 Naval Reserve retirement points, and will be credited upon successful completion of the course. These points are creditable to personnel eligible to receive them under current directives governing retirement of Naval Reserve personnel. Naval Reserve retirement credit will not be given for this course if the student has previously received retirement credit for any TRADEVMAN 1&C NRCC or ECC.

COURSE OBJECTIVE

The basic objective of this course (RTM/NRCC package) is to help the individual student meet the professional (technical) qualifications for advancement to TRADEVMAN 1st and to TRADEVMAN Chief. By completing this course the student will demonstrate his understanding of course materials by correctly answering questions in the following subject areas: the advancement requirements of the TD rating; some billets available to TDs; administration in the TD community; organization of Navy Supply; supervision of maintenance and operation of TD equipments; principles of air conditioning; simulator motion systems; application and maintenance of closed-circuit TV, including optics; digital simulator systems, including troubleshooting; and simulator motion pictures.

While working on this nonresident career course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval nonresident career courses may include a variety of items -- multiple-choice, true-false, matching, etc. The items are not grouped by type; regardless of type, they are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Some courses use many types of items, others only a few. The student can readily identify the type of each item (and the action required of him) through inspection of the samples given below.

MULTIPLE-CHOICE ITEMS

Each item contains several alternatives, one of which provides the best answer to the item. Select the best alternative and erase the appropriate box on the answer sheet.

SAMPLE

s-1. The first person to be appointed Secretary of Defense under the National Security Act of 1947 was
1. George Marshall
2. James Forrestal
3. Chester Nimitz
4. William Halsey

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-1	■	C	■	■	

TRUE-FALSE ITEMS

Determine if the statement is true or false. If any part of the statement is false the statement is to be considered false. Erase the appropriate box on the answer sheet as indicated below.

SAMPLE

s-2. Any naval officer is authorized to correspond officially with a bureau of the Navy Department without his commanding officer's endorsement.

The erasure of a correct answer is also indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-2	■	CC	■	■	

MATCHING ITEMS

Each set of items consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Specific instructions are given with each set of items. Select the numbers identifying the answers and erase the appropriate boxes on the answer sheet.

SAMPLE

In items s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions.

A. Officers	B. Departments
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Assistant for Disbursing	3. Supply Department
s-6. Communications Officer	

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-3	■	C	■	■	
s-4	C	■	■	■	
s-5	■	■	C	■	
s-6	C	■	■	■	

How To Score Your Immediate Knowledge of Results (IKOR) Answer Sheets

	1 T	2 F	3	4	
1	■	C	6	■	1
2	C	9	■	9	2
3	■	■	C	■	
4	CC	12	■	■	1

Total the number of incorrect erasures (those that show page numbers) for each item and place in the blank space at the end of each item.

Sample only

Number of boxes erased incorrectly	0-2	3-7	8-
Your score	4.0	[✓ 3.9]	3.8

Now TOTAL the column(s) of incorrect erasures and find your score in the Table at the bottom of EACH answer sheet.

NOTICE: If, on erasing, a page number appears, review text (starting on that page) and erase again until "C", "CC", or "CCC" appears. For courses administered by the Center, the maximum number of points (or incorrect erasures) will be deducted from each item which does NOT have a "C", "CC", or "CCC" uncovered (i.e., 3 pts. for four choice items, 2 pts. for three choice items, and 1 pt. for T/F items).

Assignment 1

The TD Rating; Administration and Supply

Text: Pages 1-25

In this course you will demonstrate that learning has taken place by correctly answering training items. The mere physical act of indicating a choice on an answer sheet is not in itself important; it is the mental achievement, in whatever form it may take, prior to the physical act that is important and toward which nonresident career course learning objectives are directed. The selection of the correct choice for a course training item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a physical act such as drafting a memo, cannot readily be determined by means of objective type course items; however, you can demonstrate by means of answers to training items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the mental acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a course by indicating the correct answers to training items.

The comprehensive objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The detailed objectives in each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are learning objectives and items are teaching items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This self-study course is only one part of the total Navy training program; by its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful training program.

Learning Objective: Recognize elements of the enlisted rating structure and how TDs advance within that structure, and identify requirements for advancement, including source publications, occupational standards, PAR, and PQS.

1-1. Which of the following publications lists the minimum professional requirements for advancement?

1. Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards
2. Bibliography for Advancement Study
3. Training Information Procedures (TIPS)
4. Training Manuals and Correspondence Courses

1-2. The purpose of the Nonresident Career Course is to
  1. supplement the text of the training manual
  2. outline the career pattern for Tradevmen
  3. assist the trainee in the training required to fulfill his job requirements
  4. provide a review of the occupational standards for Tradevmen

1-3. What function is served by the NEC structure?
  1. It classifies officer and enlisted personnel
  2. It identifies personnel and billets in manpower authorizations
  3. It identifies officer and enlisted personnel who have special skills
  4. It is a special classification method used by the aviation community

1-4. Which ratings have been established in order that personnel may be properly utilized within the scope of a general rating where specialization is required?
  1. Service ratings
  2. Special ratings
  3. Emergency ratings
  4. All the above

In items 1-5 through 1-7, select from column B the NEC category referred to by each description in column A.

A. Descriptions	B. Categories
1-5. Related to a specific rating	1. Special
	2. Rating
1-6. Not related to any particular rating	3. Entry
1-7. TD-7599 or DG-9710	

1-8. What are the basic professional duties of the TD?
  1. Instructing in the performance of military duties and in the use of training devices
  2. Maintaining training devices and assuming leadership in the accomplishment of military duties
  3. Maintaining training devices and using training devices to instruct individuals and groups
  4. Assuming leadership in the accomplishment of military duties and using training devices to instruct individuals

1-9. The duties of a senior Tradevman are such that he should be proficient as which of the following?
  1. As a supervisor and instructor only
  2. As a supervisor and technician only
  3. As an administrator and supervisor only
  4. As an administrator, supervisor, and technician

1-10. The time that a TD spends each day in study should result in which of the following?
  1. Higher pay with advancement in rating
  2. Improved efficiency with a feeling of accomplishment
  3. Greater pride with higher morale
  4. All of the above

1-11. What should personnel assigned to you be told relative to advancement?
  1. Eligibility for advancement amounts to actual promotion once all training requirements are met
  2. A good training record and high written examination scores are sufficient to ensure advancement
  3. Advancement in rating is automatic if satisfactory training progress is made
  4. Promotion quotas, written examination scores, length of service, and performance marks all affect advancement possibilities

1-12. The publication which delineates the minimum skill requirements for advancement in rating of naval personnel is the
  1. Naval Aeronautic Publications Index, NAVWEPS 00-500
  2. Training Publications for Advancement in Rating, NAVPERS 10052 (Series)
  3. Manual of Navy Enlisted Manpower and Occupational Standards, NAVPERS 18068 (Series)
  4. List of Training Manuals and Correspondence Courses, NAVPERS 10061 (Series)

1-13. The professional requirements for TD1 and TDC are given in the Occupational Standards Manual as
  1. knowledge factors only
  2. knowledge factors and military factors
  3. practical factors and knowledge factors
  4. task statements

1-14. The Tradevman rating is listed under Occupational Field 11 which limits the assignment of Tradevman to aviation activities.

1-15. For advancement, enlisted personnel in any paygrade need to demonstrate proficiency in
1. military requirements
2. the handling of lower rated men
3. administrative as well as technical duties
4. the tasks specified for the next higher pay grade, and may be required to demonstrate proficiency in the tasks specified for lower paygrades

1-16. The Personnel Advancement Requirement (PAR) program is designed to
1. supplement the record of practical factors
2. replace the military requirements examinations
3. evaluate the overall abilities of an individual in a day-to-day work situation
4. provide emphasis to a detailed checkoff list for the applicable rate

1-17. Which of the following paygrades is/are exempt from the PAR program?
1. E3 only
2. E3, E8, and E9
3. E8 and E9 only
4. E4, E5, E6 and E7

1-18. Which section of the PAR pamphlet contains a list of task statements?
1. Formal school requirements section
2. Administrative requirements section
3. Training requirements section
4. Occupational and military ability requirements section

1-19. Which of the following statements correctly states the relationship between occupational standards and PQS?
1. The occupational standards are equipment specific, PQS are general
2. The occupational standards are general statements, PQS are equipment specific
3. Both are stated in specific terms
4. Both are stated in general terms

1-20. Which section of the PQS explains how to use PQSs?
1. The introduction
2. The 100 Series
3. The 200 Series
4. The 300 Series

In items 1-21 through 1-23, select from column B the PQS section (series number) referred to by each description in column A.

	A. Descriptions	B. PQS Sections
1-21.	Outlines and references the necessary material for a proper theory background	1. 100 Series 2. 200 Series
		3. 300 Series
1-22.	Breaks down the equipment or systems into functional sections	4. 400 Series
1-23.	Consists of the qualification cards	

1-24. Once individuals have satisfactorily completed the PQS qualifications, when, if ever, must they requalify?
1. Upon reenlistment
2. Annually
3. Upon transfer to a different activity
4. Never

1-25. Which of the following is most inclusive regarding material which should be studied by a TD who is preparing for the Navy-wide advancement examination?
1. The mandatory and recommended study material listed for TDs in Bibliography for Advancement Study, Occupational Standards, NAVEDTRA 10052 (Series)
2. The subjects covered in the Occupational Standards Manual
3. The mandatory study material listed for TDs in Bibliography for Advancement Study, NAVEDTRA 10052 (Series)
4. Publications related to the professional aspects of the TD rating, and those relating to military requirements

1-26. Tradevman 1 & C, NAVEDTRA 10378 (Series), is classified as which of the following?
1. A basic manual
2. A rating manual
3. A subject matter manual
4. A reference manual

1-27. The reason why study suggestions 3 and 6 are included in the list of eight study suggestions given in your textbook is that in following them you
1. are able to peg each subject to an individual standard as given in the Occupational Standards Manual
2. familiarize yourself with the aims and contents of the manual and relate the subject areas to your past experiences, thereby creating an excellent learning situation
3. write an outline of the manual which will be a valuable reference for future study
4. are able to separate the military qualifications from the professional qualifications in the textbook

1-28. The use of Enlisted Nonresident Career Courses is encouraged because
1. an idea of how much you have learned from training manuals can be obtained by taking them
2. these courses assist you in mastering training manual information
3. mandatory Rate Training Manuals can be completed by passing the Enlisted Nonresident Career Courses
4. of all the above

1-29. What is the final requirement for promotion to Senior and Master Chief?
1. Demonstrated qualities of leadership
2. Successful completion of Navy-wide examination
3. Recommendation by the commanding officer
4. Selection by a regularly convened board

- Refer to figure 1-1 in your textbook in answering items 1-30 through 1-33.

1-30. At what paygrade does the TD have the first opportunity to apply for chief warrant officer (W-2)?
1. E-6
2. E-7
3. E-8
4. E-9

1-31. The minimum years of service required for enlisted personnel to be eligible for appointment to LDO is
1. 6
2. 8
3. 12
4. 20

1-32. To be eligible for appointment directly to LDO, enlisted personnel must be in which of the following paygrades?
1. E-6 through E-8 only
2. E-4 through E-9 only
3. E-6 through E-9 only
4. E-7 through E-9 only

1-33. In order for MCPOs to attain the rank of LTJG, they must hold the rank of
1. ensign only
2. ensign or W-4
3. W-2 or W-3
4. W-4 only

1-34. Which of the following is an important ability that must be developed as you advance in rating?
1. Impressing others with your job knowledge
2. Reading technical material
3. Speaking and writing in a manner understandable by others
4. writing detailed, complete instructions concerning work procedures

1-35. As a senior petty officer, your authority rests with which of the following?
1. The position occupied
2. The leadership qualities exhibited
3. The degree of specialized knowledge and skills
4. The authority conferred by the commanding officer

Learning Objective: Point out procedures and skills involved in office administration and supervision, and recognize the responsibilities of senior TDs in personnel and training program supervision.

1-36. The petty officer who understands his position in the organization realizes that his professional duties include which of the following?
1. Demanding discipline among his men
2. Attending to the needs and welfare of his men
3. Ensuring a high state of morale among his men
4. Ensuring that his part of his division's mission is satisfactory

1-37. When a petty officer has been given the responsibility of setting up an office, his filing system should be set up in accordance with
1. NAVCOMPT Manual
2. Training Equipment Guide, NAVTRADEV P-530-2
3. Navy Directives System, SECNAV Instruction P5215.1 (Series)
4. Navy Correspondence Manual, SECNAV Instruction 5216.5 (Series)

1-38. The main divisions of naval files are set up in terms of the
1. year
2. subject
3. purpose
4. addressee

1-39. Where can you find the instructions for completing the Enlisted Duty Preference Form (NAVPERS 1306/63)?
1. Enlisted Transfer Manual, chapter 9
2. Enlisted Transfer Manual, chapter 2 or the form itself
3. Training Equipment Guide, NAVTRADEV P-530-2
4. U.S. Navy Regulations, chapter 16

1-40. Which of the following statements is correct concerning submission of NAVPERS 1306/63?
1. It must be submitted 30 days after arrival at a new duty station
2. It can be submitted 10 months prior to PRD or EAOS
3. It can be submitted any time your duty preference changes
4. It must be submitted 6 months prior to PRD

1-41. If a shipment of spare parts arrives at a training device activity in damaged condition resulting from improper loading, the damage is reported on
1. Form DD 6 and Standard Form 361
2. Form NTEC 4720/4
3. Form NAVPERS 1306/63
4. Form DD 1342

1-42. The Naval Training Equipment Center maintains an inventory of training equipment valued at what minimum value?
1. $ 200
2. $ 500
3. $ 1,000
4. $10,000

1-43. Training device instructors should be cognizant of which of the following?
1. Lesson plans must be followed to the letter
2. Most instruction centers around demonstration by the instructor
3. methods of instruction may vary from one student to another
4. Due to the importance of standardization, methods of instruction should never vary from one student to another

1-44. In planning a training program, what is a reasonable amount of time to designate per day for on-the-job training?
1. Fifteen minutes
2. Thirty minutes
3. One hour
4. Two hours

1-45. Which of the following statements is correct relative to how work assignments should be planned?
1. Each worker is always assigned the job in which he is most skilled
2. All observers should be kept away from anyone doing an unusually difficult job
3. Each worker is always assigned the job in which he is least skilled so that he may learn new skills
4. a worker who lacks skill in a certain type of work should have a chance to practice with a skilled worker

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Learning Objective: Relative to cognizance symbols, identify their meaning and their utilization, point out aspects of funds appropriation, and recognize parameters of CNET field engineering service and of equipment modification.

1-46. The cognizance symbol assigned to APA spare parts for training devices is
1. "1O"
2. "2O"
3. "8N"
4. "2N"

1-47. An appropriation of government funds for specific purposes is authorized by
1. CNO
2. SECNAV
3. DCNO (Air)
4. Congress

1-48. What correlation exists between Navy appropriations and allocations?
1. Appropriations are made by bureaus or offices from allotments made by Congress
2. Allocations are made by bureaus or offices from appropriations authorized by Congress
3. Both are made by Congress
4. Both are made by the Navy Department

1-49. From appropriation number 1771804.6280, it may be inferred that the appropriation is intended for
1. BUPERS
2. fiscal year 1976
3. longer than a single year
4. training, medical, and other general personnel activities of CNET

1-50. (a) What office has the responsibility for repair and replenishment of "8N" items, and (b) what command funds those operations?
1. (a) SPCC (b) NAVMAT
2. (a) ESO (b) NAVSHIPSYSCOM
3. (a) GSO (b) NAVAIRSYSCOM
4. (a) ASO (b) NAVELEX

1-51. The person responsible for proper administration of an allocation for installation, maintenance, and modification of training devices issued by CNET Support is the
1. commanding officer
2. supply officer
3. operations officer
4. special devices officer

1-52. Which of the following statements is correct concerning the issue authority for Cognizance Symbol "20" training equipment?
1. No blanket authority exists for the issue of training equipments
2. There exist approved allowances of training equipments that have a blanket authority for issue
3. Issue authority for civilian institutes rests with CNO
4. Issue authority for military branches other than the Navy must come from CNO

1-53. Generally speaking, the final step in requisitioning training equipment from NTEC is the submission of a
1. completed MILSTRIP, along with a copy of the approved letter request for each line item that has been approved
2. letter to the approval authority
3. completed MILSTRIP to the approval authority
4. completed MILSTRIP and a letter of request to the approval authority

1-54. What are the restrictions, if any, on local procurement of non-stock-numbered training equipment repair parts?
1. Repair parts must always cost $100 or less
2. Repair parts may be purchased locally, whatever their cost, if the equipment is not fully operational
3. All repair parts costing $100 or more must be purchased locally
4. There are no restrictions

1-55. As a general rule, any item of plant property last inventoried on 30 June 1976 will be inventoried again not later than
1. 1 January 1979
2. 30 June 1977
3. 30 June 1981
4. 30 June 1979

1-56. When it becomes necessary to prepare property record forms for cognizance "20" material, the TD should consult which of the following?
1. NAVTRADEVCEN Inst. 7321.2 (Series)
2. Navy Comptroller Manual, Vol. 3
3. Training Equipment Guide, NAVTRADEV P-530-2
4. All the above

1-57. Blocks of Navy identification numbers affixed to cognizance "20" material at a naval air station are assigned by the
1. fiscal officer of the air station
2. commanding officer of the air station
3. bureau chief having management control
4. head of the department accountable for the equipage

1-58. What is the preferred method for reporting excess training devices to NTEC?
1. Letter
2. Standard Form 120
3. Standard Form 120A
4. DD Form 1342

1-59. When you report excess training devices to NTEC, itemized deficiency lists are required for training devices valued above what minimum amount?
1. $100
2. $200
3. $300
4. $500

In items 1-60 through 1-63, select from column B the disposition instructions for each item listed in column A.

A. Items	B. Instructions
1-60. Scrap	1. Disposed of locally
1-61. No value as scrap	2. OPNAVINST 5510.1
1-62. Classified device	3. NAVSUP Manual Vol. II
1-63. Lost device	4. DD Form 1348-1

1-64. Which of the following is NOT an area of utilization assistance provided to field units by CNET Support field activities?
1. Attainment of instructor acceptance of devices
2. Instruction in the effective use of devices
3. Maintenance of training devices
4. Adaptation of devices to training programs

1-65. A need for utilization assistance is based upon the
1. size of the device and the installation assistance required
2. number of personnel that will be assigned to operate the device
3. cost and complexity of the device and its importance to the training program
4. number of personnel that will be included in the instruction program for the equipment

1-66. Which of the following is an area or phase of training device operation for which CNET Support field engineering service is NOT available?
1. Administration
2. Repair
3. Installation
4. Maintenance

1-67. A request for assistance of a field engineer for a two-month training program beginning 1 June should be sent to NTEC no later than
1. 2 March
2. 2 April
3. 2 May
4. 2 June

1-68. Which of the following is NOT in itself a purpose on which to base a modification request?
1. To modernize and adapt to new training
2. To increase safety in equipment operation
3. To improve housekeeping
4. To decrease maintenance requirements

1-69. A nonaviation activity may perform a modification on a training device only after having received approval of a request which was submitted on Form
1. DD-787
2. 6ND-NTEC 4700/2
3. 6ND-NTEC 4720/2
4. NAVAIR 3069

1-70. Completion of a modification to a training device is reported on Form
1. 6ND-NTEC 4720/2
2. 6ND-NTEC 4720/4
3. 6ND-NTEC 4700/2
4. NAVTRADEV P-530-2

1-71. To hasten minor repairs to a Cognizance Symbol "20" training device by the NAVAIRSYSCOM Naval Rework Facility, the controlling activity should first contact the CNET Support field activity representative.

Assignment 2

Supervision; Principles of Air Conditioning

Text: Pages 26-49

Learning Objective: Identify publications necessary in TD work, and recognize supervisory and maintenance responsibilities of the senior TD in a shop.

2-1. Which of the following sources should the TD consult to obtain information regarding the basic operational principles of a particular training device?
1. Field Service Bulletin
2. Training Device Logbook
3. Handbook of Operation and Maintenance
4. Training Device Logbook and Field Service Bulletin

2-2. As a man advances in the TD rating, his duties require he become more skillful as
1. a technician, supervisor, and administrator
2. a supervisor and technician only
3. a technician and administrator only
4. an administrator only

2-3. Which of the following is NOT a responsibility of a TDC who is supervising the maintenance of training devices assigned to a squadron?
1. Requisitioning supplies and equipment
2. Maintaining high morale among his men
3. Keeping constantly alert for unsafe conditions and practices
4. Formulating command policy regarding personnel assignments

2-4. Proper indoctrination of a new TD produces an immediate effect on his
1. morale
2. abilities
3. moral courage
4. physical capabilities

2-5. The planning of the TD repair shop to provide for optimum operational facilities is the responsibility of
1. NTDC
2. the leading TD
3. NAVSUPSYSCOM
4. the commanding officer

2-6. In areas of high humidity, a cloth containing light oil should be used to wipe tools. However, care should be taken to avoid getting oil on which of the following?
1. Saws
2. Pliers
3. Diagonal cutters
4. All the above

2-7. An inspecting officer may justly decide a shop is poorly supervised if he notices which of the following?
1. Housekeeping is poor
2. Supervisor is absent
3. Storage arrangements are nonstandard
4. High-usage supplies are stored in open, unguarded containers

2-8. One nonresident career course recommended for strikers working in toolrooms is
1. Mathematics, Vol. I
2. Tools and Their Uses
3. Fluid Power
4. Basic Electricity

2-9. The degree of accountability required for a particular shop tool is determined in large part by the tool's pilferage classification and its
1. size
2. value
3. usage
4. complexity

2-10. The development of safety consciousness is best achieved by means of
1. periodic lectures
2. continual on-the-job safety emphasis
3. painting and marking dangerous machines and areas
4. prominent posting of safety regulations and safety posters

2-11. When new personnel are assigned to the TD shop, the petty officer in charge is responsible for which of the following?
1. Winning their confidence
2. Informing them of the type of work done in the shop
3. Showing them his interest in helping them advance
4. All the above

2-12. When a supervisor approaches a new member of his crew for the first time, his primary concern should be to
1. secure the new member's respect and confidence
2. encourage the new member to discuss his problems
3. impress the new member with the importance of discipline
4. convince the new member that he should make himself at home in the activity

2-13. The work of the Navy supervisor centers around the handling of
1. personnel
2. materials
3. tools and machines
4. records and reports

2-14. The basis of success for a good TD supervisor is
1. localization of system and component troubles
2. a knowledge of fundamentals only
3. logical reasoning coupled with a knowledge of fundamentals
4. the ability to read schematic diagrams coupled with intelligent use of test equipment

2-15. The principle that underlies effective troubleshooting of electronic devices is that trouble is best located by working from the
1. general to the specific
2. general cause to the effect
3. probable cause to the symptom
4. most specific to the most general

2-16. If he is already familiar with the device and with the appropriate test equipment, a TD usually begins to troubleshoot a trainer by
1. substituting tubes/transistors
2. conducting a shock test
3. determining the symptoms
4. conducting resistance tests

2-17. The method of troubleshooting used most often at the unit level is
1. signal tracing
2. voltage testing
3. visual inspecting
4. resistance testing

2-18. Training device shop checks which are conducted with the idea of avoiding trouble in the future are designated as
1. shop maintenance
2. class A maintenance
3. preventive maintenance
4. corrective maintenance

2-19. During periods of use, a training device should be given a visual inspection each day, followed by a/an
1. shock test
2. voltage test
3. resistance test
4. operation inspection

2-20. To conserve labor and parts, minor discrepancies revealed during daily inspection should be noted in the trainer's logbook, and repairs made during the next rework period.

2-21. As a part of routine maintenance of trainers, it is proper procedure to tighten screws on
1. cams
2. gears
3. terminal boards
4. shaft couplings

2-22. Before schematic drawings of a training device are studied during routine troubleshooting procedures, the TD should be sure to
1. conduct preliminary tests only
2. observe controls and instruments only
3. conduct preliminary tests and realign all parts and components
4. observe controls and instruments, and conduct a preliminary trouble analysis

2-23. Which statement is correct concerning adjustments made on an operational trainer? They are made
1. when misalignment seems to be the trouble
2. only when they are required for proper operation
3. as soon as possible after the equipment is turned on
4. using only a screwdriver and sensitive test equipment

2-24. An itemized list of approved test equipment for use with a trainer is found in
1. NAVEXOS P-339
2. the ESO catalog
3. BUSHIPS Manual 297-085
4. the Handbook of Operation and Maintenance Instruction for that device

2-25. Before using test equipment in troubleshooting a flight trainer or similar device, the TD should do which of the following?

1. Adjust all major power supply voltages
2. Check the ambient temperature of the suspected chassis
3. Align all potentiometers in the suspected chassis
4. make use of the various schematics in checking and analyzing for possible causes

2-26. The nature and frequency of maintenance problems associated with a specific device can best be discovered by

1. reading the logbook for that device
2. studying applicable Field Service Bulletins
3. corresponding with the manufacturer of the device
4. consulting the Handbook of Operation and Maintenance for that device

2-27. When a leading TD is setting up work assignments, his first concern should usually be for the

1. job that is to be done
2. morale of his senior personnel
3. morale of his lower-rated personnel
4. training possibilities of the job

2-28. How extensive should a supervisor's instructions be to a maintenanceman when he assigns a repair job?

1. The supervisor should tell him how to do the job and why the job is to be done
2. The supervisor should merely tell him what to do, not how or why he is to do it
3. The supervisor should tell him how to do the job, but he should not bother him with the reason for doing it
4. The supervisor should tell him why the job is to be done, but he should not attempt to tell him how to do it

2-29. The best way for a supervising TD to learn the capabilities of his people is to

1. interview each one
2. observe them at work
3. devise and conduct performance tests with this end-result in mind
4. review their performance factor marks for the past two years

2-30. Ensuring high quality repair work is one of the more important duties of the supervisor. After assigning a TD a repair job, it is important for the supervisor to

1. furnish information so the TD will have a clear picture of the total job
2. check on the progress of the work
3. inspect the finished work to ensure it meets necessary standards
4. do all the above

2-31. Before a repair job can be accepted as complete, it must be acceptable to the

1. equipment operator only
2. repairman only
3. supervisor only
4. equipment operator, repairman, and supervisor

Learning Objective: Identify methods of student involvement in training program improvement, and recognize the benefits of a good training program relative to training, and instructor and student morale.

2-32. In order to ensure that a new training device will perform its mission satisfactorily, there are certain preparations that should be made before the device is delivered for installation. These may include which of the following?

1. Modification of the building only
2. Determination of the adequacy of source power only
3. Determination of the availability of adequately trained personnel only
4. All the above

2-33. The maximum effectiveness of any training device is obtained when

1. its use is coupled with an effective training program
2. it is available for all training requirements
3. it is capably and effectively operated
4. it has a minimum downtime

2-34. Training devices are most effectively used in a training program which

1. ensures the greatest utilization of the time that training devices are available
2. provides training for personnel in the latest techniques of training device operation
3. is well managed and which changes to meet new training requirements
4. embodies all the above

2-35. In a well managed training program, when are curriculum deviations permitted?

1. When a majority of the students request them
2. Only when the prescribed program is changed
3. When done by a supervisor, but only in his area of instruction
4. When done according to the best judgment of the class instructor

2-36. There is NO need for the inclusion of quality control procedures in a training program that is administered efficiently.

2-37. Which of the following is correct concerning the information taught in a training program?

1. It is based only upon procedures from textbooks
2. It is brought up to date only when errors are brought to the attention of the school
3. It is subject to constant research to ensure correct procedures are used in the air
4. It is of concern only as it ensures uniformity of operation by all operators

2-38. Which of the following statements is correct concerning the effect of a training device malfunction on a training program?

1. It may produce undesirable training practices and misinformed students
2. It provides an excellent opportunity for maintenance and repair training
3. It has little effect on student training, and encourages operator ingenuity in devising substitute training procedures
4. It may improve instruction, since the instructor should be capable of using alternate teaching methods which do not include a training device

2-39. Which item of a quality control program, if neglected, not only reduces training effectiveness but also seriously affects student and instructor morale?

1. Instructor training
2. Equipment maintenance
3. Scheduling procedures
4. Instruction uniformity

2-40. Which of the following rules should be followed in scheduling trainers?

1. Keep crewmembers together in training sessions as much as possible
2. Separate crewmembers into different training sessions as much as possible
3. Fill quotas for training time by using crewmembers who have recently completed the course
4. Allow most of the better students to receive their allotted training time before arranging for other students

2-41. When tape recorders are unavailable, the best way to check on the effectiveness of one of your instructor's training methods is to

1. monitor his training sessions personally
2. interview his fellow instructors
3. interview the instructor
4. interview his students

2-42. In practice, information from the students which may be used to improve the quality of the training program is best obtained by

1. personal interviews
2. written comments
3. questionnaires and personal interviews
4. questionnaires and written comments

2-43. The value of a questionnaire is increased when a signature is required since most students want their opinions known.

2-44. What method has been found to be most successful in advising an instructor of his low performance evaluation?

1. Ridicule
2. Group discussions
3. Constructive criticism
4. Published evaluation reports

2-45. Which of the following subjects should NOT be included in the agenda of a meeting of the training program staff?

1. Discussion of an individual instructor's poor performance
2. Assurance that all procedures are correctly taught
3. Recommendations from instructors concerning program improvement
4. Discussion of changes necessitated by new training program revisions

2-46. Why should on-the-job training be required of all prospective instructors?
1. To acquaint them with actual procedures
2. To ensure they observe an experienced instructor
3. To ensure they receive instruction from an experienced instructor
4. To accomplish all the above

2-47. One of the elements most essential to keeping an instructional program current is obtaining comments from all possible sources.

Learning Objective: Recognize air conditions controlled by air conditioning systems, and indicate usage characteristics of associated refrigerants.

2-48. True air conditioning involves controlling air temperature and what other air conditions?
1. Humidity and cleanliness only
2. Cleanliness and distribution only
3. Distribution and humidity only
4. Distribution, humidity, and cleanliness

2-49. Which of the following statements is correct concerning most refrigerants currently in use in air conditioning systems?
1. They have a boiling point higher than that of water
2. They operate with a close-to-atmospheric pressure in the system
3. They absorb heat when changing from gas to liquid
4. They tend to increase refrigerant leakage in the system

2-50. Of the refrigerants listed below, which one is nontoxic and nonexplosive?
1. Refrigerant-12
2. Ammonia
3. Sulfur dioxide
4. Methyl chloride

2-51. Refrigerant-12 is characterized as being caustic to which of the following gaskets?
1. Rubber
2. Neophrene
3. Synthetic
4. Copper

2-52. Approximately how much refrigerant must a five-ton air conditioner boil off per hour to maintain its rated capacity?
1. 1,000 lbs
2. 1,176 lbs
3. 12,000 lbs
4. 60,000 lbs

2-53. Which of the following statements is correct regarding Refrigerant-12?
1. It is highly explosive when exposed to an open flame
2. It possesses the highest heat absorption capacity of any refrigerant
3. Because Refrigerant-12 is nontoxic, there is little danger in breathing it in concentrated amounts
4. Because Refrigerant-12 easily absorbs water-laden air, moist air entering the air conditioning system can cause a freezeup in the system

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Learning Objective: Identify names, states, and locations of refrigerants in the refrigeration cycle, and recognize functions and operating characteristics and principles of and maintenance considerations relating to air conditioning system components.

- Refer to figure 4-1 in answering items 2-54 and 2-55.

2-54. The high-pressure side of the refrigeration cycle commences at the
1. discharge side of the compressor
2. discharge side of the thermal expansion valve
3. output side of the condenser
4. output side of the receiver

2-55. Suction pressure is another term for the low-pressure of the refrigerant in the line connected from the
1. condenser to the evaporator
2. compressor to the heat exchanger
3. liquid receiver to the expansion valve
4. expansion valve to the compressor

2-56. Which of the following is the correct flow of the refrigerant in the refrigeration cycle?
1. Evaporator coil → heat exchanger → compressor → receiver → expansion valve → heat exchanger → condenser coil
2. Compressor → evaporator coil → heat exchanger → receiver → heat exchanger → expansion coil → condenser coil
3. Compressor → condenser coil → receiver → heat exchanger → expansion valve → evaporator coil → heat exchanger
4. Receiver → heat exchanger → expansion valve → condenser coil → compressor → heat exchanger → evaporator coil

2-57. In an open reciprocating type of compressor, which of the following actions occur during the piston's upstroke?
1. Low pressure gas enters cylinder, gas compresses, discharge valve opens
2. Intake valve closes, high pressure gas enters cylinder, gas compresses, discharge valve opens
3. Intake valve closes, low pressure gas enters cylinder, discharge valve opens, high pressure gas is delivered
4. Intake valve closes, gas compresses, discharge valve opens, high pressure gas is delivered

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In items 2-58 through 2-60, select from column B the statement associated with each type of compressor listed in column A.

A. Compressors	B. Statements
2-58. Open reciprocating	1. It produces very little vibration
2-59. Semihermetic reciprocating	2. It has a direct motor and a compressor housed in the same casing
2-60. Full hermetic reciprocating	3. It will support large systems
	4. It requires specialized or factory servicing

2-61. Refer to figure 4-3. During operation of a rotary compressor of the type illustrated, which of the following components prevent(s) the compressed gas from escaping through the suction side of the compressor?
1. A rotary blade and an eccentric disc
2. An eccentric disc only
3. A stationary blade and a rotary blade
4. A stationary blade and an eccentric disc

2-62. When an electrical motor and a compressor are mounted in the same sealed container, the motor torque is developed through what means?
1. Induction
2. Compression
3. Brushes
4. Sliprings

2-63. A hermetic motor is connected to run a compressor. Which of the following procedures may be used to break loose the motor if it is stuck?
1. Rotate the motor shaft by hand
2. Apply source power directly to the compressor
3. Apply an above-normal voltage to the motor
4. Replace the brushes and/or points in the motor

2-64. Refer to figure 4-4. Which of the following statements is correct concerning the heat-sensitive device illustrated in the figure?
1. If the device opens, it will automatically close when the heat is sufficiently reduced
2. If the device opens, it must be reset manually
3. The bimetal element is sensitive to heat from the heating coil only
4. The bimetal element is sensitive to heat from all sources other than the motor's coils

2-65. The function of the condenser section of an air conditioner is to
1. absorb British thermal units
2. dissipate heat
3. convert liquid to gas
4. restrict external air circulation

2-66. An air-cooled condenser's surface area is considered to be which of the following areas?

1. The area of the fins only
2. The outside area of the refrigerant tubing only
3. The inside area of the refrigerant tubing only
4. The area of the fins and the outside area of the refrigerant tubing

2-67. Refer to figure 4-1. High-pressure liquid refrigerant leaves the receiver through a/an

1. opening at the top of the tank
2. opening near the top of the tank
3. quill from the bottom of the tank
4. king valve in the bottom of the tank

Assignment 3

Principles of Air Conditioning; Simulator Motion Systems

Text: Pages 49-78

Learning Objective (continued): Identify names, states, and locations of refrigerants in the refrigeration cycle, and recognize functions and operating characteristics and principles of, and maintenance considerations relating to air-conditioning system components.

3-1. An expansion valve performs its function of changing high-pressure refrigerant to low-pressure liquid by
1. increasing the P3 pressure in the expansion valve
2. increasing the P2 pressure in the expansion valve
3. providing a small orifice and a capillary tube through which the liquid must pass
4. providing a small orifice and an expansion chamber through which the liquid must pass

3-2. The function of a capillary tube is to convert
1. high-pressure gas into high-pressure liquid
2. low-pressure gas into low-pressure liquid
3. low-pressure liquid into high-pressure liquid
4. high-pressure liquid into low-pressure liquid

- Refer to figure 4-10 in answering items 3-3 and 3-4.

3-3. Which of the following conditions exist in the expansion valve?
1. Needle valve unseated, refrigerant entering valve chamber, bellows not expanded
2. Force generated by P2 and F2 greater than that generated by P1 and F1, needle valve seated, bellows not expanded
3. Bellows expanded, valve unseated, force generated by P1 and F1 greater than that generated by P2 and F2, needle valve seated, refrigerant entering valve chamber
4. Bellows expanded, force generated by P1 and F1 greater than that generated by P2 and F2, needle valve unseated, refrigerant entering valve chamber

3-4. In addition to its function as a constricting device, the expansion valve serves to
1. prevent flooding the low side of the system
2. convert hot liquid refrigerant to a cold gas
3. convert refrigerant gas to a liquid state
4. prevent high-pressure liquid refrigerant from reversing its direction of flow

3-5. Refer to figure 4-11. What type of energy initiates the action which causes the needle valve to open?
1. Chemical
2. Heat
3. Mechanical
4. Electrical

- Refer to figure 4-1 in answering items 3-6 and 3-7.

3-6. Relative to operation of the air-conditioning system illustrated in the figure, to what does the term evaporation refer?
1. Dissipation by the condenser coils of moisture taken from the air
2. Changing of the refrigerant from a liquid to a gas in the evaporator coils
3. Changing of the refrigerant from a liquid to a gas in the liquid receiver
4. Dissipation by the evaporator coils of moisture taken from the air

3-7. In what unit in the refrigeration cycle does dehumidification occur?
1. Compressor
2. Liquid receiver
3. Condenser coils
4. Evaporator coils

3-8. Refer to figure 4-14 and assume that a pressure gauge has been installed in the gauge port. What should be the position of the valve plunger in order for the gauge to indicate gas line pressure?
1. Seated back
2. Cracked from the back seated position
3. Seated forward
4. Cracked from the forward seated position

In items 3-9 through 3-13, select from column B the accessory most closely related to each of the accessory functions listed in column A.

	A. Functions	B. Accessories
3-9.	To provide a means for quickly checking the physical condition of the refrigerant	1. King valve
3-10.	To trap the refrigerant in the receiver and condenser lines	2. Heat exchanger
3-11.	To precool refrigerant before the refrigerant enters the evaporator	3. Drier-strainer
3-12.	To remove water from the refrigerant	4. Sight glass
3-13.	To remove foreign matter from the refrigerant	

3-14. During a routine maintenance check of an air conditioner, it is noted that the permanent type filter has collected very little foreign matter. The most likely reason for the small accumulation of dirt is that the
1. filter was not treated properly with adhesive
2. filter was installed backwards
3. air drawn through the filter contained very little foreign matter
4. mechanism for drawing air thorugh the filter was not functioning properly

3-15. Refer to figure 4-15. Assume the adjustment lever has been set at 82° F. Which of the following factors exercise(s) control over the bimetal element's movement?
1. The current from the power source only
2. An ambient temperature change only
3. The magnetic attraction of a detent and current from the power source
4. The magnetic attraction of a detent and an ambient temperature change

3-16. Refer to figure 4-17. Failure of the humidistat's sensing element to respond to a change in ambient air humidity would result in the humidifier becoming inoperative.

3-17. Operation of the condenser fan should normally result in
1. an increase in refrigerant temperature
2. changing the refrigerant from a liquid to a gas
3. lower compressor head pressure
4. an increase in ambient air temperature

In items 3-18 through 3-20, select from column B the safety control most closely related to each of the functions listed in column A.

	A. Functions	B. Safety Controls
3-18.	It protects units near the electric heaters from excessive ambient temperatures	1. High-pressure cutout switch 2. Low-pressure cutout switch
3-19.	It automatically vents the refrigerant if the pressure becomes dangerously high	3. Fusible plug 4. Thermal cutout
3-20.	Under normal operating conditions, it keeps compressor head pressure from becoming excessive	

Learning Objective: Identify conditions indicative of a malfunctioning air-conditioning system, and recognize maintenance procedures to be followed and safety precautions to be observed by a TD when repairing an air-conditioning system.

3-21. Which of the following statements is correct concerning preventive maintenance and corrective maintenance of air-conditioning equipment?
1. Preventive maintenance should be performed in accordance with the manufacturer's manual, and corrective maintenance in accordance with NAVTRADEVCENINST 10230.1
2. Corrective maintenance should be performed in accordance with the manufacturer's manual, and preventive maintenance in accordance with NAVTRADEVCENINST 10230.1
3. Both should be performed in accordance with the manufacturer's maintenance manual
4. Both should be performed in accordance with NAVTRADEVCENINST 10230.1

In items 3-22 through 3-26, refer to table 4-1. Select from column B the frequency at which each preventive maintenance action listed in column A should be performed if the unit is operated 12 hours each day.

	A. Preventive Maintenance Actions	B. Frequency
3-22.	Clean air filter	1. Bimonthly
3-23.	Check refrigerant charge	2. Monthly
3-24.	Check humidifier's water level	3. Weekly
		4. Daily
3-25.	Check for refrigerant leaks with a leak detector	
3-26.	Clean drier filter, sight glasses, and heat exchanger, and check their general condition and mounting security	

3-27. In checking an air-conditioning system, you discover an oil leak in the area of the compressor. What should you conclude and what action should you take?
1. There is a refrigerant leak; purge the working space, locate the leak with a leak detector, repair the leak, and recharge the system if necessary
2. There is a refrigerant leak; purge the working space, recharge the system, and repair the leak
3. There may be a refrigerant leak; check for a leak with a leak detector and repair the leak if found
4. There is an oil leak; estimate the amount of oil lost and add this amount to the compressor

- Refer to table 4-2 in answering items 3-28 and 3-29.

3-28. Which of the following conditions in a malfunctioning air-conditioning system may be corrected by replacing the suction valve?
1. High suction pressure
2. A leaking crankcase
3. An inoperative condenser fan
4. Low head pressure

3-29. A low refrigerant state in an air-cooled condenser is indicated by
1. high head pressure, low suction pressure, or a sweating compressor
2. high head pressure or high suction pressure, and a continuously running compressor
3. low head pressure or high suction pressure, and a sweating compressor
4. low head pressure, low suction pressure, or a continuously running compressor

3-30. Which of the following sequences should a TD follow when installing a manifold pressure gauge?

1. He should back seat the discharge service valve, install the tube connector fitting, connect the flexible charging line to the discharge fitting, and crack the pressure gauge valve
2. He should back seat the discharge service valve, install the tube connector fitting, connect the flexible charging line to the discharge fitting, crack the discharge service valve tighten the gland nut, and purge the pressure gauge charging line
3. He should back seat the suction service valve, install the tube connector fitting, connect the flexible charging line to the suction fitting, crack the suction service valve, tighten the gland nut, and purge the compound gauge charging line
4. He should install the tube connector fitting into the discharge service valve, purge the tube connector fitting, connect the flexible charging line to the connector fitting, and purge the pressure gauge charging line

3-31. Air can be removed from the lines in an air-conditioning system by purging what from the system?

1. Liquid refrigerant only
2. Cooled moisture only
3. Liquid refrigerant and cooled moisture
4. Vaporized refrigerant

3-32. When evacuating and purging an air-conditioning unit, why must you heat both the unit and the purging gases?

1. To ensure evacuation of as much debris as possible
2. To ensure evacuation of as much trapped moisture as possible
3. To hasten vaporization of the refrigerant in the system
4. To hasten evacuation of air from the system

- Refer to figure 4-22 in answering items 3-33 and 3-34.

3-33. What valve settings should you use when adding refrigerant vapor to the low side of an air-conditioning system?

	Compressor Valves		Gauge Valves	
	Suction	Discharge	Suction	Discharge
1.	Open	closed	closed	mid-seat
2.	Closed	mid-seat	open	closed
3.	Open	closed	cracked	cracked
4.	Closed	mid seat	open	mid-seat

3-34. Which of the following forces cause(s) liquid refrigerant to enter an air-conditioning system when the refrigerant is being added to the high side?

1. Gravity only
2. Compressor suction
3. Gravity and the refrigerant container pressure
4. Gravity and the low-side suction

3-35. You light a halide torch and it immediately burns with a greenish flame. What does the color indicate?

1. The air contains refrigerant gas
2. The torch is low on fuel
3. The flame height must be adjusted
4. A soap and water solution has gotten on the torch wick

3-36. The minimum acceptable bending radius for 3/4-inch copper tubing is

1. 2 1/2 inches
2. 3 1/4 inches
3. 3 3/4 inches
4. 5 1/4 inches

3-37. Which of the following statements is correct regarding the soldering of copper tubing?

1. Heat for melting the solder should come directly from the torch flame
2. Heat for melting the solder should come from the heated fittings
3. Never feed the solder to the joint from more than one point
4. Never apply flux to the tubing ends and fittings

3-38. A mixture of different type refrigerants must NOT be used in an air-conditioning system.

3-39. When the evaporator in an air-conditioning system is covered with a layer of insulating frost, it is an indication that the
1. system is operating normally
2. evaporator is blocked internally with debris
3. refrigerant charge is low
4. system is cooling above normal capacity

3-40. Which of the following steps should you take if Refrigerant-12 gets in your eyes?
1. Rub your eyes briskly
2. Apply mineral oil or olive oil to your eyes
3. Cover your eyes with goggles
4. Treat your eyes as if they were sunburned

3-41. Operating an air conditioner when a service valve is closed may result in physical damage to the
1. compressor and personnel
2. service valve
3. interconnecting lines
4. brazed or soldered fittings

Learning Objective: Recognize similarities and differences between pneumatic and hydraulic fluid power systems, and indicate operating characteristics and component functions of a basic fluid power system, including open- and closed-center systems.

3-42. The similarity between hydraulic and pneumatic fluid power systems is correctly indicated by which of the following statements?
1. The basic components of the systems are essentially the same
2. The basic components of the systems are identical and interchangeable
3. Both systems depend upon internal lubrication by the system fluid
4. Both 1 and 3 correctly indicate the similarity

3-43. Which component of a hydraulic fluid power system performs the same function as the receiver in a penumatic fluid power system?
1. Reservoir
2. Compressor
3. Actuator
4. Selector valve

3-44. The gas in a pneumatic fluid power system differs from the fluid in a hydraulic fluid power system in which of the following respects?
1. The gas provides the force required to operate the system
2. The gas is stored in the receiver under pressure
3. The gas is used for one operation and then exhausted from the system
4. The gas differs from the fluid in all the above respects

In items 3-45 through 3-47, select from column B the hydraulic/pneumatic fluid power system component that performs each function listed in column A.

	A. Functions	B. Components
3-45.	Converts mechanical energy into fluid energy	1. Actuator 2. Receiver
3-46.	Directs the flow of fluid through the system	3. Selector valve 4. Pump
3-47.	Converts fluid energy into mechanical energy	

3-48. Which of the following statements about the most common types of actuators used in fluid power systems is true?
1. Motors provide rotary motion and cylinders provide linear motion
2. Motors provide linear motion and cylinders provide rotary motion
3. Both motors and cylinders provide linear motion
4. Both motors and cylinders provide rotary motion

3-49. Refer to figure 5-1 in your textbook. With the control valve in the "down" position, the piston in the actuating unit will move
1. to the left
2. to the right
3. to a neutral position
4. either to the right or to the left, depending upon its position prior to control valve positioning

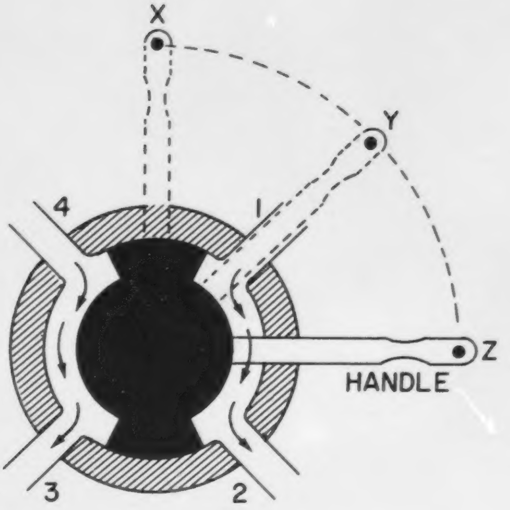

Figure 3A.--Control valve.

- Refer to figure 3A in answering items 3-50 and 3-51. This figure shows a cutaway view of a valve that operates in the same manner as the control valve shown in figure 5-1 of your textbook. The darkened area rotates with the handle to direct fluid flow through the valve.

3-50. When the handle is moved to position X, fluid can flow between which lines?
1. 1 and 2 only
2. 1 and 3, 2 and 4
3. 1 and 4, 2 and 3
4. 1 and 2, 3 and 4

3-51. When the handle is moved to position Y, fluid flow, if any, will occur between which lines?
1. 1 and 4, 2 and 3
2. 2 and 4 only
3. 2 and 3 only
4. Fluid will not flow

In item 3-52 through 3-54, refer to figure 5-2 in your texbook. Select from column B a function of each component listed in column A.

A. Components

3-52. Accumulator

3-53. Pressure regulator

3-54. Check valve

B. Functions

1. To bypass fluid to the reservoir in case of excessive pressure buildup in the system
2. To allow the flow of fluid in only one direction
3. To store enough fluid under pressure to provide for emergency operation of certain actuating units
4. To unload or relieve the power driven pump when the desired system pressure is reached

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3-55. The hand pump of a closed-center hydraulic system can be used for which of the following purposes?
1. To precharge the accumulator
2. To check and troubleshoot many of the system components
3. To serve as an emergency means of operating the system
4. To do both 2 and 3 above

3-56. Which of the following statements about an open-center hydraulic system is NOT correct?
1. The directional control valves are connected in parallel
2. There is no pressure in the system when the actuators are idle
3. The system may employ any number of subsystems with a directional control valve for each
4. The pump circulates fluid from the reservoir, through the directional control valves, and back to the reservoir

3-57. Closed-center hydraulic systems are the most widely used because they
1. provide smooth operation of their actuators
2. eliminate continuous system pressurization
3. operate very rapidly
4. do all the above

Learning Objective: Recognize aspects of Device 21C5, including cab motion, system pressures, and purpose of various components.

3-58. The cab motion of Device 21C5 functions in what two planes?
1. Pitch and yaw
2. Roll and yaw
3. Pitch and vertical
4. Roll and pitch

3-59. The following three statements describe the operation of the 21C5 diving trainer. Select the proper order of operation.

A. The computer solves equations of submarine mass and motion

B. The students input, to a computer, orders for steering and diving

C. The computer outputs attitude command signals to the motion system

1. ABC
2. BCA
3. CAB
4. BAC

Refer to figure 5-6 in answering items 3-60 through 3-62.

3-60. Which of the following conditions is/are necessary to activate the hydraulic power?
1. Electrical power on
2. Electrical power on and cab gate closed
3. Electrical power on and platform unlocked
4. Electrical power on, cab gate closed, and platform unlocked

3-61. What type of output is sent from the dynamic computing system to the servo valve?
1. Electrical
2. Mechanical
3. Hydraulic
4. Pneumatic

3-62. The purpose of the flow regulating valve is to
1. establish minimum/maximum rates of flow to the servo valve
2. limit maximum angular rate of cab motion
3. limit required amount of hydraulic fluid
4. establish rate of flow to the servo valve

Refer to figure 5-7 in answering items 3-63 and 3-64.

3-63. What is the principle of operation of the variable volume pump?
1. Variable length of stroke
2. Variable rpm
3. Variable diameter pistons
4. Pilot-operated input valve

3-64. What pressures should be indicated by gauges B and C, respectively?
1. 3000 psi and 800 psi
2. 800 psi and 3000 psi
3. Both 800 psi
4. Both 3000 psi

In item 3-65 through 3-68, select from column B the hydraulic subsection(s) that utilize(s) each component listed in column A.

A. Components

3-65. Differential relief valves set at 2500 psi

3-66. Actuator with a 22-inch stroke

3-67. Emergency leveling control valves

3-68. Flow regulator set at 3 gpm

B. Hydraulics

1. Pitch
2. Roll
3. Both pitch and roll

Assignment 4

Simulator Motion Systems; CCTV

Text: Pages 77-108

Learning Objective: Recognize operational characteristics of Device 2F101.

- Items 4-1 through 4-14 refer to the motion system used by Device 2F101.

4-1. The term "washout" when applied to this motion system means the
1. abrupt reduction of the motion cue
2. gradual reduction of the motion cue
3. abrupt onset of the motion cue
4. gradual onset of the motion cue

4-2. The solution of the motion problem is accomplished for this device in the same manner as that used for Device 21C5, a two-degree-of-freedom device. Solutions are arrived at by
1. dynamic equations solved by a digital computer
2. static equations solved by a digital computer
3. dynamic equations solved by an analog computer
4. static equations solved by an analog computer

4-3. The following items, when placed in the correct order, trace the flow of hydraulic fluid through the system. Place the items in the correct order and then select the correct alternative below.

A. Boost pump (2000 psi) to the motion pump

B. Motion pump to the distribution manifold

C. Gravity fed hydraulic fluid from the reservoir to the boost pump

D. Motion cylinders to the heat exchanger

E. Distribution manifold to the motion cylinders

F. Heat exchanger to the reservoir

1. C, A, B, D, E, F
2. F, D, E, B, A, C
3. C, A, B, E, D, F
4. E, D, F, C, A, B

4-4. What is the function of the accumulator assembly?
1. It handles overflow from the distribution manifold
2. It acts as a bleeder valve at high system pressures
3. It acts as a booster at peak demands by the system
4. It lowers system pressure as system pressure approaches 1200 psi

- Refer to figure 5-11 in answering items 4-5 through 4-14.

In items 4-5 through 4-7, select from column B the safety limit related to each activation point listed in column A.

	A. Activation Points	B. Units
4-5.	>150° F	1. (6A)
4-6.	<100 gal.	2. (29)
4-7.	Partially closed	3. (30)

In items 4-8 through 4-10, select from column B the pressure that is found in the lines between the points listed in column A.

	A. Points	B. Pressures
4-8.	From 13A to the motion actuators	1. 30 psi
		2. Gravity
4-9.	From 5 to 13A	3. 1200 psi
4-10.	From 4 to 5	4. 78 psi

4-11. The controller or brain of the motion actuator is the servo-controlled flow control valve number
1. (63)
2. (64)
3. (65)
4. (66)

4-12. Select the data below that best indicates the ram and rod conditions of the motion cylinders.

	Ram	Rod
1.	Supply pressure 1200 psi	Pressure transducer attached
2.	Variable driving force	Supply pressure 1200 psi
3.	Supply pressure 1200 psi	Variable driving force
4.	Low pressure side	Supply pressure 1200 psi

4-13. Trace the flow of fluid from the input hose (76) through the valves to the cylinder (71).
1. Four-way, feedback, flow control, deceleration
2. Four-way, deceleration, flow control, shuttle
3. Four-way, shuttle, flow control, deceleration
4. Shuttle, four-way, flow control, deceleration

4-14. Describe the inputs and outputs of the control loading system.

	Inputs	Outputs	
		HI	LO
1.	Separate pump, only	1400 psi	1400-1600 psi
2.	Main distribution manifold, only	50-1600 psi	1400 psi
3.	Separate pump and main distribution manifold required	1400 psi	100 psi
4.	Separate pump or main distribution maifold	1400 psi	50-1600 psi

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Learning Objective: Relative to CCTV and commercial TV systems, identify transmission methods, bands, and associated standards, and recognize units and their functions, and the operating principles of circuits involved in generating TV transmissions.

4-15. What is the major difference between a CCTV system and a commercial telecasting system?
1. Pickup cameras
2. Methods of transmitting picture and sound
3. Monitor screen size
4. Monitor image (black and white versus color)

4-16. Which of the following statements is correct concerning the broadcasting method of AM radio signals and television video signals?
1. In both methods, amplitude modulation is used
2. In both methods, frequency modulation is used
3. AM radio signals are amplitude modulated, whereas television video signals are frequency modulated
4. Both signals are limited to line-of-sight reception

4-17. What is the bandwidth allowance for each (a) VHF and (b) UHF television channel?
1. (a) 4MHz (b) 6MHz
2. (a) 4MHz (b) 4MHz
3. (a) 6MHz (b) 4MHz
4. (a) 6MHz (b) 6MHz

● Vestigial is defined as that which pertains to the remnant or remaining part.

4-18. The vestigial sideband method of television transmission is that method of transmission whereby only a portion of the
1. sidebands is transmitted
2. upper sideband is transmitted
3. lower sideband is transmitted
4. 6MHz bandwidth is transmitted

4-19. What are the basic units found in a television system?
1. Camera, sync generator, and video recorder
2. Video recorder, camera, and monitor
3. Camera, monitor, and control unit
4. Optical multiplexers, special effects, video recorders, and audio units

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In items 4-20 through 4-22, select from column B the description of each major CCTV unit listed in column A.

	A. Units		B. Descriptions
4-20.	Monitor	1.	Video signal producing unit
4-21.	Camera	2.	Heart of CCTV system
4-22.	Control Unit	3.	Picture producing unit

4-23. Considering the scanning method of TV picture presentation, how is it possible for the viewer to see an entire picture?
1. Each element constitutes an entire picture
2. The elements are presented in such rapid succession that they appear to be an entire picture
3. The video portion of the signal is presented as a whole, while the syncronizing portions of the signal result from the scanning process
4. Each time the electron beam scans from one side of the image to the other, all the picture elements are scanned and presented as a whole

4-24. Refer to figure 6-3. The picture portion of the TV signal results from
1. a beam of light being swept across the globules of the mosaic in syncronism with the electron beam sweep
2. each globule discharging a current, representative of the degree of brightness in its portion of the mosaic, through a load resistor
3. the globules being caused to emit electrons in relation to the speed of the electrons in the electron beam which scans the mosaic
4. the scene image being focused on the metal coating on which the globules are mounted, and the globules being scanned by the electron beam

4-25. Neglecting time allotted for retrace time, presentation of a complete frame requires the electron beam sweep from left to right across the mosaic how many times?
1. 30 times
2. 525 times
3. 15,750 times
4. 525 + 30 times

4-26. In mosaic scanning, what is the significance of the number 15,750?
1. It is the number of lines the electron beam must sweep in order to present a full picture
2. It is the number of globules in 30 picture frames, and therefore is the horizontal sweep frequency in hertz
3. It is the number of lines in each 30-picture frame increment that is lost due to retrace time, and is twice the horizontal sweep frequency in hertz
4. It is the number of times per second that the electron beam sweeps from one side of the mosaic to the other, and therefore is the horizontal sweep frequency in hertz

4-27. The horizontal oscillator operates at a frequency that produces 525 lines per frame, but many of these lines are not effective in producing vertical detail because
1. during horizontal flyback they are blanked out
2. during vertical retrace they are blanked out
3. of interlace scanning
4. they are lost during "front porch" and "back porch" time

4-28. Interlaced scanning serves the purpose of reducing flicker by
1. causing each field to remain visible for one-fifteenth second
2. assuring that all lines necessary to picture presentation are scanned
3. causing the picture to appear as though it were presented 30 times per second rather than 60 times
4. causing the picture to appear as though it were presented 60 times per second rather than 30 times

4-29. In addition to returning the electron beam to the top of the screen after a field has been scanned, the vertical deflection coils also cause the beam to be
1. blanked at the end of each field
2. blanked at the end of each horizontal line
3. pulled steadily across the image plate
4. pulled steadily downward as it sweeps across the image plate

4-30. Blanking pulses are used primarily to
1. stop the flow of electrons which make up the electron beam
2. cause the electron beam to retrace the line it just scanned
3. trigger the horizontal and vertical sweeps in the receivers
4. synchronize the camera's electron beam sweep with those in the receiver

4-31. At what instant during the horizontal sweep process is the blanking pulse removed so that a visible line may be traced?
1. At the instant flyback is begun
2. An instant after the sweep is begun
3. An instant before the sweep is begun
4. At the instant the sweep is begun

4-32. In the American flag, color saturation is exhibited by the color(s)
1. white
2. red and blue
3. red and white
4. white and blue

4-33. What are the three primary colors used in color television?
1. Red, green, and blue
2. Red, white, and blue
3. White, black, and red
4. Cyan, magenta, and yellow

Learning Objective: Recognize types, functions, characteristics, and proper care and focusing of TV camera lenses, indicate sources of danger to lenses, and identify TV terms and their meanings.

4-34. A lens' focal length is defined as the
1. ratio of its diameter to its thickness
2. ratio of the curvature of its surface to the focal plane
3. distance from the lens' optical center to the most distant object which can be focused on the focal plane
4. distance from the lens' obtical center to the surface upon which it focuses an object viewed at infinity

4-35. Refer to figures 6-7 and 6-8. A comparison between the various angle factors shows which of the following?
1. The angle of maximum coverage and the angle of illumination are identical
2. The angle of view determines the maximum possible size of the angle of field
3. The angle of field determines the maximum possible size of the angle of view
4. The circumference of the total circle of illumination circumscribes the area which determines the maximum usable size of the focal plane

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In items 4-36 through 4-38, select from column B the color term referred to by each definition in column A.

	A. Definitions	B. Terms
4-36.	Produced by different wavelengths	1. Hues
4-37.	Amount of dilution by white light	2. Luminance
4-38.	Brightness of a color	3. Saturation

4-39. When a camera is focused at infinity, the focal plane is located
1. one focal length behind the lens
2. one focal length in front of the lens
3. two focal lengths behind the lens
4. two focal lengths in front of the lens

4-40. What is the relationship between the f/number, focal length, and the diameter of the effective aperture of a lens?
1. $fF = D$
2. $f/D = F$
3. $f = F/D$
4. $D/f = F$

4-41. The mechanical device on a camera which controls the amount of light that passes through a lens may properly be called
1. stops
2. a luminance selector
3. aperture
4. any of the above

4-42. Consider the formula $f = \frac{F}{D}$. If D is increased and the distance to the subject remains the same, which of the following statements is correct?
1. The f/number decreases and the depth of field decreases
2. The f/number decreases and the depth of field increases
3. The f/number increases and the depth of field increases
4. The f/number increases and the depth of field decreases

4-43. The critical or optimum aperture of a camera is an opening which is attained by setting the camera to
1. the largest f/number
2. the smallest f/number
3. two stops from the largest aperture
4. two stops from the smallest aperture

In items 4-44 through 4-47, select from column B the lens property that will be damaged by each of the lens damage sources listed in column A.

	A. Lens Damage Sources	B. Lens Properties
4-44.	Fumes, steam, salt spray	1. Internal structure
4-45.	Stowing with lens mount horizontal	2. Surface coating or polish
4-46.	Heat and moisture	
4-47.	Impact on lens mount	

Learning Objective: Indicate the purpose of an optical system multiplexer, and recognize operating principles and characteristics of various types of TV camera tubes and the circuits and components used with them in a TV camera.

4-48. In TV broadcasting, a multiplexer is an optical system used to
1. record scenes from slide film on motion picture film
2. vary the illumination of a scene that is being picked up by a TV camera
3. provide a means by which a TV scene may be recorded on motion picture or slide film
4. provide a means by which motion picture or slide film may be used to present a scene for the camera

4-49. An indication of the sensitivity of a pickup tube is the
1. amount of light necessary for minimum acceptable performance
2. number of horizontal lines that can be reproduced
3. amount of light that produces maximum current flow from the image plate
4. rapidity with which the image plate responds to a change from minimum light to maximum light

4-50. In a vidicon camera tube, electrons from the photoconductive layer are released by light. Why do they travel to the opposite side rather than across the photoconductive layer?
1. The potential gradient is much less in this direction than it is across the photoconductive layer
2. The potential gradient is much greater in this direction than it is across the photoconductive layer
3. The force of impinging electrons in the beam drives them through the layer
4. The force of impinging photons from the photocell drives them through the layer

4-51. The vidicon camera tube employs the principle that
1. acceleration of the electrons in the scanning beam is varied in proportion to the intensity of the light striking each molecule
2. electrons from the scanning beam pierce the darker areas of the photoconductive layer more easily than they pierce the lighter areas
3. the resistance of the photoconductive layer changes in proportion to the intensity of the light striking it
4. the resistance of the photoconductive layer changes in proportion to the density of the electron beam striking it

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In items 4-52 through 4-54, select from column B the semiconductor type that is formed from each plumbicon elements listed in column A.

	A. Elements	B. Semiconductor
4-52.	Tin dioxide	1. P
4-53.	Lead oxide	2. I
4-54.	Doped lead oxide	3. N

4-55. The most sensitive camera pickup tube is the
1. plumbicon
2. vidicon
3. image orthicon

4-56. From the standpoint of producing a good video signal, it is desirable to have a high-amplitude signal output from a camera tube because
1. high frequencies are less prominent in high-amplitude signals
2. a high-amplitude signal is easier to amplify at a uniform rate
3. fewer amplifying stages are necessary, and therefore less noise is introduced
4. high and low frequencies appear in approximately the same ratio in a high-amplitude signal

4-57. One of the major problems in TV signal amplification arises from the fact that the signal is composed of a wide range of frequencies. What method is used to obtain nearly uniform amplification of the entire signal?
1. The camera pickup output is made as uniformly as possible
2. Each amplification stage contains two amplifiers--one for high and one for low frequencies
3. Special circuits are included to boost or peak those signals that are discriminated against
4. A cathode follower is used to restore any portion of the signal that becomes distorted in the amplifying process

4-58. Refer to figure 6-20. What is the purpose of Q3?
1. To amplify the video signal
2. To isolate the video signal
3. To rectify the video signal
4. To match the impedance between the camera unit and the control unit

● Refer to figure 6-21 in answering items 4-59 through 4-63.

4-59. What pins of the vidicon tube receive (a) vertical blanking and (b) horizontal blanking signals?
1. (a) 5 (b) 3
2. (a) 5 (b) 2
3. (a) 1 (b) 2
4. (a) 2 (b) 1

4-60. What type of peaking circuits are used in the output of the Darlington Amplifier stage to (a) develop the signal and (b) couple the signal to the base of Q3?
1. (a) Shunt (b) shunt
2. (a) Series (b) series
3. (a) Series (b) shunt
4. (a) Shunt (b) series

4-61. C10, CR2, and the R23, C13 combination provide coupling, rectification, and filtering, respectively, for the bias on Q6. What components serve the same purpose for Q5?
1. C15, CR3, and the R28, C14 combination
2. C14, CR2, and the R28, C15 combination
3. C15, CR2, and the R29, C16 combination
4. C14, CR3, and the R29, C16 combination

4-62. What function is served by relay K1? It is used for
1. low-voltage protection
2. horizontal sweep protection
3. vidicon tube protection
4. vertical sweep protection

4-63. What are the functions of S1 and S2?
1. They are used to troubleshoot the camera
2. They are used by the protective circuitry to isolate the vidicon tube
3. They are used for special effects; S1 inverts the image, S2 provides a mirror image
4. They are used to apply power to the sweep circuits; S1 for horizontal, S2 for vertical

4-64. In a color camera, how do the three camera pickup tubes select their assigned colors from a multicolor scene?
1. The scene's colors are filtered and reflected to the proper tube
2. Each tube utilizes an electronic filter to filter out the color its signal represents
3. Each tube contains a mosaic of globules of the color its signal represents
4. Phase shifting and reflection separate the colors and route them to the proper tube

In items 4-65 through 4-67, select from column B the color signal designator for each color video signal listed in column A.

	A. Video Signals	B. Designators
4-65.	Orange or cyan	1. Y
4-66.	Green or purple	2. Q
4-67.	Luminance	3. I

4-68. Which of the following statements is correct concerning the gamma rating of a TV camera tube?
1. A gamma of 1 is always desirable
2. The gamma of a perfectly linear camera tube is 0
3. The gamma rating describes the linearity of the input signal of the tube as compared to its output
4. The gamma rating is a comparison of the linearity of the output signal to the input signal

4-69. Aperture correction circuits are used in televisions to restore the sharp leading and trailing edges of the video signal. What information is contained in the edges?
1. Fine picture detail
2. Gross picture detail
3. Luminance information
4. Gamma corrections

Assignment 5

CCTV Optics, Maintenance, and Applications

Text: Pages 109-145

Learning Objective: Recognize functions, pulse, and frequency characteristics and principles of operation of TV video circuits associated with composite and color TV signal generation and transmission.

5-1. Refer to figures 6-25 and 6-26. From the explanation of the composite signal received by the receiver/monitor, and by referring to figures 6-25 and 6-26, it can be concluded that the
   1. video portion is used to vary the density of the scanning electron beam
   2. lower 75 percent contains all signal and control voltages necessary for picture presentation on the screen
   3. front and back porches permit video to appear for a short time before and after the sync pulse
   4. sync pulses atop the blanking pulse start the electron beam sweeping left to right across the screen

5-2. Refer to figure 6-26. The figure shows that the electron beam is acted upon by the horizontal sweep signal for 54 microseconds of each full line, and that video is visible for
   1. that same length of time
   2. 63.5 μsec
   3. 53.34 μsec
   4. the entire line except for the flyback time

5-3. The vertical pulse blanks the picture each time the electron beam in the receiver reaches the
   1. left side of the screen
   2. right side of the screen
   3. start of a field
   4. end of a field

5-4. Refer to figures 6-27 and 6-28. A study of the synchronizing pulses in figures 6-27 and 6-28 shows that equalizing pulses are transmitted before and after the vertical sync pulse in order to
   1. compensate for the serrations in the vertical sync pulse
   2. cause a higher-than-normal charge to build up on the capacitor in the vertical oscillator trigger
   3. assure that the vertical oscillator will be triggered at the proper time at the end of a full-line field
   4. assure that the capacitor in the vertical oscillator trigger will be properly charged before the appearance of the vertical sync pulse

5-5. Which of the following components of a colorplexed composite video signal is used by a black and white receiver?
   1. R-Y
   2. B-Y
   3. G-Y
   4. Y

5-6. The chrominance signal contains two sets of data--saturation and hue. How is this data developed?
   1. By developing a chroma subcarrier varying in amplitude (saturation) and phase (hue)
   2. By developing two subcarriers that are frequency modulated
   3. By developing a chroma subcarrier that is frequency and amplitude modulated
   4. By developing two subcarriers equal in frequency and phase

5-7. What (a) frequency range and (b) type of detail requires the transmission of luminance data only?
   1. (a) 0-5 MHz
   2. (a) 5-15 MHz (b) fine
   3. (a) 1.5 MHz and above (b) very fine
   4. (a) 0-5 MHz (b) fine

5-8. Refer to figure 6-33. If red at 30 percent is added to blue at 11 percent, the resulting color is
1. cyan
2. white
3. yellow
4. magenta

5-9. What is done to ensure a phase lock (2:1) between the horizontal and vertical scanning signals?
1. The scanning signals are generated in a common master oscillator
2. Linear feedback signals are used
3. High gain amplification is employed
4. The sync signals (horizontal and vertical) are generated in a common master oscillator

5-10. Refer to figure 6-34. What function is served by Q9?
1. Stabilization of master oscillator
2. Amplification of power line input
3. Modulation of power line and vertical drive output
4. Demodulation of power line and vertical drive output

● Refer to figure 6-35 in answering items 5-11 and 5-12.

5-11. The free running output frequency of this oscillator is determined by the values of
1. C4 and R4
2. C5 and C6
3. C5 and R8
4. C6 and T1

5-12. The feedback loop of Q2 functions as a variable
1. capacitor only
2. inductor only
3. resistor only
4. inductor or capacitor, depending on the amplitude of the input

5-13. Refer to figures 6-36 and 6-37. What is the normal phase relationship between the vertical drive pulses and the 60 Hz reference signal? The vertical pulses appear
1. on the positive peaks of the 60 Hz signal only
2. on the negative peaks of the 60 Hz signal only
3. on either the positive or negative peaks of the 60 Hz signal
4. when the 60 Hz signal passes through zero

5-14. Refer to figure 6-38. Which of the following components could be modified to change the countdown ratio?
1. R27, R28, and X6
2. T2, X6, and R28
3. R29, R30, and R31
4. C17, R30, and R31

5-15. Refer to figure 6-40. What signal determines when clamping will occur?
1. Horizontal drive
2. Vertical drive
3. Video output
4. Blanking output

5-16. What is the relationship, if any, between the circuits in figures 6-40 and 6-41?
1. There is no relationship
2. Normally, the sync adding network feeds the blanking insertion
3. Normally, the blanking insertion circuits feeds the sync adding network
4. Both of the circuits feed a composite video amplifier circuit

---

Learning Objective: Recognize functions and operating principles and characteristics of TV receivers, circuits, and components, and identify TV component locations and picture tube identification codes.

5-17. The front end of a TV receiver serves to
1. amplify the signals from the antenna, both video and audio, and separate the video from the audio before the mixing stage
2. select the desired video frequency and amplify and mix it with a locally-generated signal to produce an intermediate frequency
3. amplify the desired input and mix it with a locally-generated RF signal to produce intermediate audio and video frequencies
4. amplify the desired video and audio signals from the antenna and provide a locally-generated signal to mix with the video to produce a video amplitude-modulated intermediate frequency and a frequency-modulated audio intermediate frequency

5-18. One advantage of using FETs instead of ordinary transistors in RF tuners is the low noise characteristic of the FET. Why do the FETs generate less noise?
1. Because the FET uses hole flow vice electron flow
2. Because the FET uses electron flow vice hole flow
3. Because the FET uses either hole flow or electron flow but not both
4. Because the FET uses both hole flow and electron flow

5-19. Refer to figure 7-3. What is the relationship between the current flowing from source to drain and the voltages on the gates?
1. The current is inversely proportional to the voltage
2. The current is directly proportional to the voltage
3. The current is inversely proportional to the square of the voltage
4. The current is directly proportional to the square of the voltage

5-20. Another application of the dual-gate MOSFET shown in figure 7-3 is as a
1. mixer amplifier
2. detector
3. demodulator
4. tuning circuit

5-21. What is the principle of operation of the varactor diode used in solid-state tuning circuits?
1. The varactor is a solid-state diode that acts like a variable resistor
2. The varactor is a solid-state diode that acts as a capacitor whose capacitance varies inversely with the amount of reverse bias applied across the diode
3. The varactor diode acts as an inductor whose inductance varies directly with the amount of reverse bias applied across the diode
4. The varactor diode acts as either an inductor or capacitor, depending upon the amount of bias applied

5-22. Refer to figure 7-4. In actual practice, the varactor cannot provide a complete tuning range for all VHF/UHF channels. The tuning range is extended by switching in
1. another varactor
2. different values of resistors
3. another variable capacitor
4. a different inductor

5-23. Video IF is higher than audio IF because
1. the video is amplitude modulated and the audio is frequency modulated
2. the sum of the local oscillator and the video carrier frequencies is greater than the sum of the local oscillator and the audio carrier frequencies
3. partial removal of the lower video sideband lowers both the video and the audio carrier frequencies, but the audio is lowered more than the video
4. the difference between the local oscillator and the video carrier frequencies is greater than the difference between the local oscillator and the audio carrier frequencies

5-24. Even if the lower sideband were entirely suppressed, the signals adjacent to the carrier would be stronger than those progressively away and higher. This uneven distribution could be remedied by
1. aligning the local oscillator to produce an IF signal lower than would normally be produced
2. aligning the local oscillator to produce an IF signal higher than would normally be produced
3. tuning the IF amplifiers away from the center IF frequency so that the lows are amplified less than the highs
4. tuning the IF amplifiers away from the center IF frequency so that the highs are amplified less than the lows

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In answering item 5-25 through 5-28, select from column B the descriptive statement that pertains to each trap listed in column A.

A. Traps

5-25. Series

5-26. Parallel

5-27. Absorption

5-28. Degenerative

B. Statements

1. Designed to reduce the gain of the amplifier at the desired frequencies
2. Proper operation is dependent upon the circuit having a high Q
3. It is a parallel resonant circuit
4. The trap is inductively coupled to the load inductor

5-29. Which of the following traps is the most effective?
1. Degenerative
2. Series
3. Bridged-T
4. Parallel

● Refer to figure 7-7 in answering items 5-30 through 5-34.

5-30. What is the center of the IF frequency passed by this amplifier?
1. 41.25 MHz
2. 42.17 MHz
3. 43.8 MHz
4. 45.75 MHz

5-31. How is the wide bandpass accomplished through the coaxial cable?
1. By using two traps at the input to the amplifier
2. By using mutual coupling between the output and input coils
3. By impedance coupling the amplifier stages
4. By detuning the input and output amplifier coils

5-32. What type of traps are used at the input?
1. Bridged-T and series
2. Bridged-T and absorption
3. Series and parallel
4. Parallel and degenerative

5-33. What input components provide the same function as LA 39 and LA 54, respectively, on the output?
1. LA 2, LA 5
2. Mixer output coil, LA 2
3. Mixer output coil, LA 5
4. LA 5, LA 2

5-34. What method is used to match impedances between stages?
1. Split capacitors shunting a peaking coil
2. Split capacitors in series with a peaking coil
3. Split resistors in parallel with a peaking coil
4. Split inductors in parallel with a capacitor

5-35. What is the determining factor in whether a positive or a negative picture phase is used in a TV receiver?
1. What phase is transmitted by the country the receiver is in (e.g. the U.S. transmits a negative picture phase)
2. What type of detectors are used
3. Where the detection takes place
4. Where the video signal is applied to the picture tube (negative to the cathode or positive to the grid)

5-36. What undesirable effect is encountered in using RC coupling in video chains?
1. The RC time constant varies with the applied frequency, which causes phase shifting
2. Carbon-molecule and capacitor-leakage noises are more prevalent at some frequencies than at others
3. The RC time constant appears shorter to some video signals and longer to others, which causes phase shifting
4. The coupling capacitor causes frequency discrimination by shunting the higher frequencies around the circuit

---

In items 5-37 through 5-39, select from column B the accomplishments of each of the circuit arrangements listed in column A.

A. Arrangements

5-37. Inductor in series with coupling capacitor

5-38. Capacitor bypasses a portion of the plate load

5-39. Inductor in series with plate load

B. Accomplishments

1. Minimize low-frequency loss
2. Minimizes high-frequency loss

● Refer to figure 7-11. It will be helpful to recall that the video portion of the signal is composed of a multitude of signals of differing frequencies and amplitudes. Only the peaks of the video are shown between the blanking pulses. Actually, the entire area between zero and the peaks is filled with complex video voltages, and the peaks show the amplitude of the strongest in relation to the blanking pulse. Note in (A) that the blanking level remains unchanged, as it should, while in (B) it varies around zero.

5-40. The dc component of a video signal is reinserted by the action of the input signal in establishing a bias on the picture tube. This accomplishes which of the following?

1. Causes the black level to vary in proportion to the average video signal
2. Maintains the proper brilliance of the picture by providing an operating reference for the video
3. Causes the black level, and therefore the sync level, to vary in proportion to the average blanking pulse amplitude
4. Maintains the proper brilliance of the picture by causing the sync pulses to operate around the zero reference

5-41. DC restoration is NOT required in TV receivers when

1. inductive tuning is employed
2. a single stage of IF amplification is used
3. a single stage of video amplification is used
4. direct coupling is used between all stages in the video amplifier section

5-42. What is the major advantage of the television intercarrier sound system over the split sound system?

1. Higher fidelity
2. Easier maintenance
3. Higher gain
4. Fewer audio stages

5-43. The sound IF frequency of 4.5 MHz is obtained by

1. beating the sound carrier and the video carrier together and selecting the signal representing their sum
2. beating the sound carrier and the video carrier together and selecting the signal representing their difference
3. beating the sound carrier of one channel with the video carrier of the adjacent higher channel and selecting the signal representing their difference
4. beating the sound carrier of one channel with the video carrier of the adjacent higher or lower channel and selecting the signal representing their difference

In answering items 5-44 through 5-47, refer to figure 7-16 and select from column B the function provided by each component listed in columnA.

A. Components

5-44. DC coupled audio amplifiers

5-45. IF amplifiers

5-46. C1L1

5-47. Q1T1

B. Functions

1. Meets the power and impedance requirements of speaker
2. Provides good bass response
3. Produces square wave signal input for quadrature detector
4. Provides necessary selectivity for IF amps

5-48. The color dot trios on the screen of a receiver are so arranged that each of the three electron beams scans

1. only the dot which its signal represents
2. all three dots at once, lighting only the dot which its signal represents
3. all three dots in succession, making three scans per line
4. each line in succession, without the necessity of interlaced scanning

5-49. A picture tube is coded 19RAP9. This code indicates which of the following?

1. The tube has a diagonal measurement of 19 inches, and the type of phosphor is RA
2. The tube uses a P9 phosphor, and the basic tube has been modified in some manner
3. The tube has had 19 modifications, has a screen that measures 9 inches diagonally, and is manufactured by RCA
4. The tube has RAP9 phosphor, and has a screen that measures 19 inches diagonally

5-50. The chrominance information is delayed for a fixed period of time so that the luminance and chrominance information will get to the CRT at the same instant.

5-51. Compared to the tuner in a monochrome receiver, the RF tuner in a color receiver has which of the following?
1. A narrower bandpass and lower signal-to-noise ratio
2. A narrower bandpass and higher signal-to-noise ratio
3. A wider bandpass and lower signal-to-noise ratio
4. A wider bandpass and higher signal-to-noise ratio

5-52. One of the important factors that must be considered at all times in a color receiver is
1. the load on the high-voltage rectifier must be constant
2. the brightness level of the incoming signal must be constant
3. automatic adjustment of the AGC controls for optimum performance
4. variable convergence of three electron beams in the picture tube

5-53. To synchronize the local color oscillator, the burst signal must consist of approximately
1. 15,750 cycles of horizontal signal
2. 60 cycles of vertical signal
3. 30 cycles of vertical signal
4. 10 cycles of color signal

5-54. The burst amplifier is keyed during the time of
1. horizontal tracing
2. horizontal retracing
3. vertical tracing
4. vertical retracing

5-55. When activated by the color burst, the color killer functions to
1. remove the bias on the bandpass tube and take it out of cutoff
2. disable the color beams
3. shift the color oscillating frequency
4. disable the color oscillator

5-56. Refer to figure 7-22. Q1 will block the operation of the chroma amplifiers if
1. a chroma video signal is present
2. a color burst is present
3. a color burst is not present
4. the 3.58 MHz oscillator is operating

5-57. What section separates the color video signal from the 3.58 MHz subcarrier signal?
1. Color killer section
2. Chroma detector section
3. Automatic frequency and phase control
4. Bandpass amplifier section

5-58. In the chroma detectors of figure 7-23, suppose the phase difference between the reference oscillator signal and the 3.58 MHz subcarrier signal is 270 degrees. Describe the output of V1.
1. Positive output
2. Negative output
3. No output
4. Maximum output

5-59. Which of the following is an advantage of high level detectors over low level detectors?
1. Higher color resolution
2. Less voltage from the high voltage regulator
3. One stage of amplification is eliminated
4. Adjustments for convergence are not necessary

5-60. Refer to figure 7-29. The green luminance signal is developed by
1. proportional amounts of red and blue luminance signals
2. the luminance signal on the cathode of the CRT
3. a 90° phase shift to the input of the detector
4. the 3.58 MHz reference signal input to the detectors

5-61. The signals that correspond to the camera video signals are combined with the luminance signal to reproduce the televised scene on the CRT. Where are these signals combined?
1. Bandpass amplifier
2. Local oscillator
3. Demodulators
4. Matrix circuit

5-62. Green luminance color signals are developed in a receiver from the red and blue luminance signals by means of
1. a voltage divider arrangement
2. a phase inverter
3. a phase shift circuit
4. an automatic frequency and phase control

5-63. Restoring the loss in phase balance that occurs during transmission of the red and and blue color signals is accomplished by providing
1. an extra video amplifier stage
2. an additional gain for the blue color signal
3. an extra sync separator for the blue color signal
4. all the above

5-64. Where in the receiver are the red, green, and blue signals in the form of the original red, green, and blue signals of the camera?
1. Individual gun amplifiers
2. Matrix
3. CRT cathode and grid
4. Convergence yoke

5-65. The amplitude of the luminance signal on the cathode of the CRT is determined by the
1. number of IF sections used
2. high voltage potential
3. convergence settings
4. brightness control setting

5-66. Refer to figure 7-28. What function is carried out by resistors R7 and R8?
1. Setting up the green and blue phosphor dots during monochrome reception to get a black-and-white picture
2. Attenuating the green and blue signals during color reception
3. Providing a feedback for the green and blue amplifier output stages
4. Balancing the delay time for the green and blue guns

5-67. Which of the following statements is correct concerning the effect of the composite TV signal on various receiver circuits?
1. The video signal varies the width of the electron beam, the blanking pulses prevent visible retrace, and the sync pulses sweep the beam horizontally and vertically to trace picture lines
2. The video signal varies the number of electrons in the beam, the blanking pulses stop emission of the beam, and the sync pulses keep the oscillators properly synchronized
3. The video signal varies the speed of the electrons in the beam, the blanking pulses stop emission of the beam and reposition it to the starting place, and the sync pulses keep the oscillators properly synchronized
4. The video signal varies the number of electrons in the beam, the blanking pulses prevent visible retrace and reposition the beam to the starting place, and the sync pulses sweep the beam horizontally and vertically to trace picture lines

5-68. The composite signal is applied to the input of the circuit shown in figure 7-30. How does the circuit remove only the sync pulses while leaving the video and blanking pulses to be routed elsewhere?
1. The tube is chosen to have plate resistance and interelectrode capacity characteristics that will not respond to the high frequencies in the video
2. The RC time constants on both charge and discharge are so short to the high frequencies in the video that the video signals and blanking pulses are ineffectual in circuit operation
3. The short RC time constant on charge and the long time constant on discharge cause a bias to be developed which prevents all signals below the blanking level from affecting circuit operation
4. The long RC time constant on charge and the short time constant on discharge cause a bias to be developed which prevents all signals below the blanking level from affecting circuit operation

Assignment 6

CCTV; Introduction to Digital Simulator Systems

Text: Pages 146-169

Learning Objective (continued): Recognize functions and operating principles and characteristics of TV receivers, circuits, and components, and identify TV component locations and picture tube identification codes.

For purposes of explaining the operation of the differentiator circuit in figure 7-32, only the horizontal sync pulses are shown being applied. However, all control pulses are applied and are timed so that their leading edges occur in time sequence with the leading edges of the horizontal sync pulses. Thus, the complete set of control pulses shown in figure 7-33 is applied to both the high-pass and the low-pass filters. The RC time constants at the inputs to the two filters are the determining factors in separating the two sync signals.

6-1. Refer to figure 7-33. Why does the vertical sync pulse appear in the output taken across the capacitor, while the horizontal and equalizing pulses do not?
   1. The horizontal and equalizing pulses, having been removed by the differentiator, are not applied to the integrator
   2. The RC time constant is short to the narrow horizontal and narrow equalizing pulses, permitting only a negligible charge on C for each
   3. The small charges placed on C by the horizontal and equalizing pulses completely leak off between pulses, but charges caused by the closely spaced vertical serrations do not
   4. The RC time constant is long to the combined widths of the serrations in the vertical pulses, and long to each horizontal and equalizing pulse, permitting the wider vertical pulse to be more effective in circuit operation

In answering items 6-2 through 6-5, refer to figure 7-35. Select from column B the component combination that performs each function listed in column A.

	A. Functions	B. Components
6-2.	Determines oscillator frequency	1. C5, C6, C8
		2. -6V dc, R1
6-3.	Compensating network (height)	3. C11
6-4.	Forms sawtooth wave for vertical trace	4. C2, R4, R5
6-5.	Isolates yoke from dc	

6-6. The horizontal oscillator is more easily disturbed by noise than is the vertical oscillator because
   1. of the longer time constant in the horizontal oscillator's input
   2. of the shorter time constant in the horizontal oscillator's input
   3. noise bursts receive greater amplification in the horizontal circuits than in the vertical circuits
   4. the frequency of machinery noise is closer to the vertical frequency than to the horizontal frequency

6-7. Refer to figure 7-37. When the oscillator frequency lags the sync pulses, which of the following statements correctly describes the operation of the phase detector?
   1. The outputs from D1 and D2 are equal and opposite causing a positive voltage to be applied to the base of Q1
   2. The output of D1 produces a positive control voltage that is applied to the base of Q1
   3. The output of D2 produces a negative control voltage, which lowers the oscillator frequency
   4. The output of D2 produces a positive control voltage, which raises the oscillator frequency

In answering items 6-8 through 6-11, refer to figure 7-37. Select from column B the component(s) that perform(s) each function listed in column A.

	A. Functions	B. Components
6-8.	Shapes horizontal output pulse	1. C4, C10, R16
		2. R6
6-9.	Course oscillator control	3. R4, R7, R8, R10
6-10.	Oscillator stabilization	4. L1
6-11.	Isolates the phase detector from the oscillator	

6-12. Refer to figure 7-38. What are the polarities of the signals at (a) the output of the oscillator, (b) the base of the buffer amplifier, and (c) the base of the horizontal output transistor?
1. (a) positive (b) negative (c) positive
2. (a) negative (b) positive (c) positive
3. (a) positive (b) negative (c) negative
4. (a) negative (b) positive (c) negative

● Refer to figure 7-39 in answering items 6-13 and 6-14.

6-13. A Zener regulator is used in which of the following?
1. 100 V supply
2. 24 V supply
3. -20 V supply
4. Picture heater filaments

6-14. What type rectifiers are used in the -20 V and +100 V circuits, respectively?
1. Half wave, full wave
2. Both half wave
3. Both full wave
4. Full wave, half wave

● Refer to figure 7-40 in answering items 6-15 and 6-16.

6-15. The purpose of L5 and C12 is to
1. rectify the +20 V output
2. act as a phase detector for the tuner
3. filter the +20 V to the tuner
4. isolate the tuner from the active filter

6-16. As the circuit warms up, the thermistor and varistor in the 290 volt B+ supply change resistances. What is the relationship between the currents through these devices?
1. Initially, maximum current flows through the varistor, minimum current through the thermistor
2. Initially, maximum current flows through the thermistor, minimum current through the varistor
3. With the set warmed up, minimum current through the thermistor, maximum current through the varistor
4. With the set warmed up, the two devices act like a voltage divider and have approximately equal currents

6-17. Why is each frame of a complete scan broken into two fields?
1. To reduce flicker by causing the screen to be more persistent
2. To minimize the coverage necessary for the beam in one line sweep, and to improve detail
3. To minimize the bandpass requirements for handling the composite TV signal, and to reduce flicker
4. To prevent the necessity of a faster horizontal scanning speed and the attendant waiting period between lines

6-18. In TV operation, what factor determines the minimum amount of RF spectrum that must be allocated for the composite signal?
1. The frequency of the channel in use
2. The power at which the signal is transmitted
3. The amount of frequency modulation of the sound signal
4. The amount of detail necessary for satisfactory viewing

6-19. IF amplifiers in a receiver are stagger tuned to prevent overlap of sound and video voltages.

6-20. When the horizontal oscillator does NOT lock into synchronization properly, what indication will be observable by the operator?
1. The picture will jump upward
2. The picture will roll downward
3. Either 1 or 2 above will occur
4. The picture will tear into diagonal segments

6-21. What is the ultimate form and destination of the output of the vertical oscillator?
1. Sawtooth current to the yoke
2. Sawtooth current to the grid of the picture tube
3. Square wave to the yoke
4. Square wave to the grid of the picture tube

6-22. Which of the following statements is correct concerning the use of a gated-beam tube in the sound section of a receiver?
1. The sound IF stage may be omitted
2. The sound must be separated from the composite signal at the mixer or first IF stage
3. The gated-beam tube performs all functions of detection and amplification required for sound production
4. An additional stage of sound IF amplification is required, but no limiter or detector is needed

6-23. Assume that monitors in a string of five readyrooms, or briefing rooms, are cable-fed by a single weather data control unit and camera, and that the monitor in room No. 5 has a raster but no picture. What should be the first step in isolating the trouble?
1. Determine if monitor No. 4 has a picture
2. Determine if the camera has a video output
3. Determine if the control unit has a video input
4. Determine if the control unit has a video input and output

6-24. Recall that in the discussion of the horizontal oscillator, it was stated that if the sync signal were lost at the input, the oscillator would free-run to prevent burning the screen. Could this account for the fact that the receiver incorporates oscillators which free-run when the input sync signals are lost, and why?
1. Yes, because without free-running oscillators the electron beam would be stationary and would burn the screen when no signal was being received
2. Yes, because without oscillators it would be impossible to amplify the received control signals sufficiently to perform control functions
3. No, because free-running oscillators are necessary in the separation of the control signals from the video
4. No, because without free-running oscillators the electron beam could not exist

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Learning Objective: Indicate TV receiver trouble symptoms and troubleshooting procedures, and recognize CCTV usage and limitation.

● Items 6-25 through 6-30 pertain to the symptom analyses in Table 7-1.

6-25. Which of the following will most likely cause the receiver screen to be darker than normal?
1. Dirty picture tube protective cover or dirty tube face
2. Decreased high voltage
3. Decreased low voltage B+
4. All the above

In items 6-26 through 6-30, select from column B the receiver section which would most likely cause each of the trouble symptoms listed in column A.

	A. Trouble Symptoms	B. Receiver Sections
6-26.	Picture tilted on screen	1. Low voltage B+
		2. Horizontal
6-27.	Sound normal, screen black	3. Yoke
6-28.	No sound, screen blank, all filaments lighted	4. Video amplifier
6-29.	Sound and raster good, no picture	
6-30.	Picture wedge-shaped, wider at top than at bottom	

6-31. The old adage, "Leave it alone if you don't know what you're doing," applies particularly to the alignment procedure in TV equipments, and TDs should never attempt alignment until they have been thoroughly trained by someone who has had experience in that detailed operation.

- Items 6-32 through 6-35 pertain to the symptom analyses in Table 7-2.

6-32. Prior to troubleshooting color circuits, you should do which of the following?
1. Troubleshoot the black-and-white sections of the set
2. Adjust the power supplies
3. Align the tuner
4. Ensure that both black-and-white and color portions of the receiver have been properly adjusted

---

In items 6-33 through 6-35, select from column B the color receiver parameter most closely related to each black-and-white symptom listed in column A.

	A. Symptoms	B. Color Parameters
6-33.	Color flashes in picture	1. White adjustment
		2. Color killer
6-34.	Nonuniform white/gray shades	3. Color purity
6-35.	Nonuniform coloring of screen	4. Convergence section

6-36. Refer to Table 7-2, section II. Which of the following symptoms will appear if a color receiver has a defective Q or I channel?
1. Color transposition
2. Missing colors
3. Color hum
4. Washed-out colors

6-37. CCTV is an excellent training aid in that it can provide which of the following?
1. A method of directing the attention of the student to a section of an illustration or a comparison of two illustrations with minimum outside distraction
2. Expeditious teaching of complex equipment by initially bringing into the classroom large, scarce, and remote equipment
3. Better classroom demonstration by magnifying small parts and giving each student a front row seat
4. All the above

6-38. Time and cost of production may be limitations in CCTV training.

6-39. Through the use of television presentations, a pilot can receive training in operations involving takeoffs and landings in which of the following situations?
1. Varying weather conditions
2. From carrier decks
3. From land bases
4. Any of the above situations

Learning Objective: Recognize the function of digital computers in digital simulators, various models of computers and their word formats, minicomputers and their effect on simulation, and examples of minicomputers being used in digital simulators.

6-40. The first paragraph of chapter 8 in your text points out that a prerequisite for study of chapter 8 is to be knowledgeable of the material in Digital Computer Basics, NAVEDTRA 10088-A.

- Figure 6-A is a functional block diagram of the ASW Submarine Attack Centers, Device 21A38. This device employs two large Control Data Corporation digital computers--the CDC 1604B and the CDC 3100. The CDC 3100 is a slave computer that contains a complex program strictly for sonar simulation. The CDC 1604B contains the main trainer program. Attack Center 1(AC1) and its sonar room form the trainee station for a Permit class submarine, AC 2 for the Skate Class, and AC 3 for the James Madison SSB(N) class of submarines. Each of the Attack Centers has an associated Instructor Station.

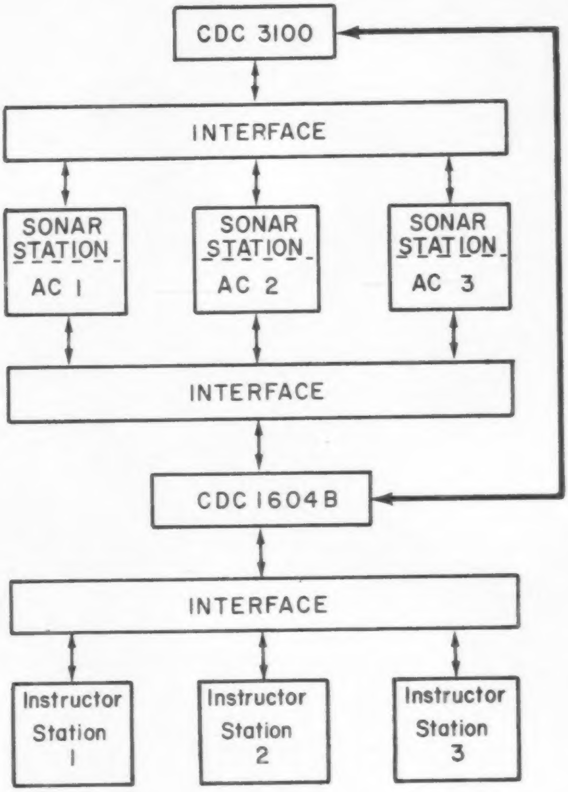

Figure 6-A.--Block diagram, Submarine Training Device 21A38.

● Refer to figure 6-A in answering items 6-41 and 6-42.

6-41. What components of device 21A38 form the training vehicle portion of the digital simulator system?
1. Attack Centers, their respective sonar rooms, and the instructor stations
2. Attack Centers and their respective sonar rooms
3. Computers and interfaces
4. Computers and instructor stations

6-42. What three major components qualify this trainer as a digital simulator system?
1. Computer, interface, and training vehicle
2. AC1, AC2, and AC3
3. Instructor stations 1, 2, and 3
4. CDC 1604B, CDC 3100, and the interfaces

6-43. The computer CANNOT communicate directly with the trainee station because of the
1. excessive amount of data sent to the trainee station
2. types of data sent to the trainee station
3. internal speed of the computer
4. discrete method of computation used by the computer

● Refer to Appendix I in answering items 6-44 through 6-48.

In answering items 6-44 through 6-47, select from column B the computer model code used by each manufacturer listed in column A.

	A. Manufacturers	B. Computer Codes
6-44.	Digital Equipment Corp.	1. DDP
6-45.	Honeywell	2. UYK
6-46.	Raytheon	3. PDP
6-47.	Sperry	4. PB

6-48. What models/types of computers are utilized by Device 21A37?
1. H-800, DDP-416, and H-316
2. DDP-12 and SEL810A
3. CDC3100 and 1604B
4. DDP-516 and H-800

6-49. What is the relationship, if any, between simulator programs and algorithms?
1. Simulator programs form the basis for algorithms
2. Algorithms form the basis for simulator programs
3. The terms are synonymous
4. The terms are unrelated

6-50. Which of the following statements concerning machine language is correct?
1. Each computer manufacturer utilizes a single machine language
2. A given machine language is unique to a model or series of computers
3. Machine languages, such as COBOL and FORTRAN are universal
4. All machine languages perform identical functions, therefore they are identical

In answering items 6-51 through 6-53, select from column B the example of an instruction that provides each function listed in column A.

	A. Functions		B. Examples
6-51.	Transfer information	1.	Load A register
6-52.	Arithmetic/logic	2.	Start tape reader
6-53.	Control	3.	Add memory to A register

- Items 6-54 through 6-56 refer to the DDP124 computer.

6-54. What are (a) the word length and (b) the memory cycle time of this computer?
   1. (a) 8 bits (b) 1.75 nanosec
   2. (a) 12 bits (b) 1.75 microsec
   3. (a) 24 bits (b) 1.75 microsec
   4. (a) 24 bits (b) 1.75 nanosec

6-55. What restriction, if any, is placed on the use of double-operand words?
   1. No restrictions; used in the same manner as a single operand word
   2. The signs of both words must be identical
   3. Only negative numbers can be used
   4. Only positive numbers can be used

6-56. What function is served by bit positions 1, 2, and 3 in the instruction word?
   1. Address modification
   2. OP-code
   3. Address field
   4. Source address

6-57. Two features of the DDP-516 NOT found on the DDP-124 are
   1. 24-bit words and integrated circuits
   2. 16-bit words and indexing
   3. 24-bit words and indirect addressing
   4. 16-bit words and paging

6-58. What computer has been used more than any other in the construction of digital simulator systems?
   1. DDP-124
   2. DDP-516
   3. NOVA 800
   4. PDP-11/45

6-59. Refer to figures 8-2 and 8-3. Compare the double precision data words of the DDP-124 and the DDP-516.
   1. 46 magnitude bits for the former, and 30 magnitude bits for the latter
   2. Sign positions of both halves of both words must be identical for both machines
   3. Sign positions of both halves of both words must be opposite for both machines
   4. 48 magnitude bits for the former, and 32 magnitude bits for the latter

---

In items 6-60 through 6-63, select from column B the function/description of some of the bits used by the word formats listed in column A.

	A. Formats		B. Functions
6-60.	Memory reference	1.	Employs 2's complement
6-61.	Input/output	2.	Bits 11-16 specify a device
6-62.	Shift	3.	Sector bit-7
6-63.	Generic	4.	Bits 1-16 specify the operation code

6-64. Minicomputers have been defined in this chapter as computers that, with minimum memory and limited I/O devices, cost less than
   1. $10,000
   2. $ 8,000
   3. $ 6,000
   4. $ 4,000

6-65. Which of the following statements is correct relative to the shorter word lengths found in minicomputers?
   1. Instruction execution time has been reduced
   2. The OP-code and memory address sections of the word are smaller
   3. The OP-code section has been expanded while the memory address section is smaller
   4. Instruction execution time has been increased

6-66. One method used to overcome the problem of a small instruction set is to
1. preprogram a multiply instruction
2. employ multiple-operation instructions
3. preprogram a divide instruction and then complement for multiplication
4. employ paging

6-67. When paging is employed, how is the memory divided?
1. Pages, sections, and chapters
2. Variable length pages
3. Fixed length pages
4. Combination fixed and variable length pages

● The fourth bit in the 12-bit instruction word of the PDP-8S indicates whether the seven-bit address in the instruction word refers to the page in which the instruction lies (in which case bit four is a one), or to the first page in memory (in which case bit four is a zero).

6-68. If the fourth bit of a PDP-8S instruction word is a zero, the address given is 23, and the instruction word is on page 20, what is the actual location addressed?
1. Page 0, address 23
2. Page 20, address 23
3. Page 20, address 43
4. Page 0, address 43

Assignment 7

Introduction to Digital Simulator Systems

Text: Pages 170-189

Learning Objective (continued): Recognize the function of digital computers in digital simulators, various models of computers and their word formats, minicomputers and their effect on simulation, and examples of minicomputers being used in digital simulators.

7-1. The various models of the NOVA computer have what feature in common?
1. The same machine language
2. The same number of addressable registers
3. The same type of memory
4. The same type of arithmetic/logic unit

7-2. What is (a) the type of memory and (b) the memory access time found in the NOVA 800?
1. (a) core (b) 600 nanosec
2. (a) disc (b) 800 nanosec
3. (a) core (b) 800 nanosec
4. (a) disc (b) 600 nanosec

7-3. In the NOVA 800 computer, what determines which word format is to be used?
1. The first three bits of the instruction word
2. The last three bits of the instruction word
3. The page or sector bit
4. The timing chain

- Items 7-4 through 7-7 relate to the NOVA 800 computer.

In answering items 7-4 through 7-7, select from column B the bit format that specifies each instruction format in column A.

	A. Instructions	B. Bit Formats	Bit position 0	1	2
7-4.	Arithmetic/logic	1.	0	0	0
7-5.	Move data	2.	0	0	1
7-6.	Jump or modify memory	3.	0	1	1
7-7.	Input/output	4.	1	1	1

7-8. In the arithmetic/logic instruction format, what function, if any, is served by bits 8-15?
1. Device code
2. Displacement
3. Not used
4. Secondary functions

7-9. Which of the following computers are upward compatible?
1. DDP124 and NOVA
2. DDP516 and PDP 11/15
3. PDP and NOVA
4. DDP516 and NOVA

In items 7-10 through 7-14, select from column B the computer indicated by each characteristic/use listed in column A.

	A. Characteristics/Uses		B. Computers
7-10.	Has the fastest access time	1.	DDP-124
7-11.	Does not employ multiple instruction word formats	2.	DDP-516
7-12.	Employs a 16-bit word but is not considered a minicomputer	3.	NOVA-800
		4.	PDP-11/45
7-13.	Employs sector addressing or paging		
7-14.	Nine are used in Device 1D23		

7-15. One of the features of the PDP 11/45 NOT found on many of the minicomputers is the
1. paging feature
2. programmed multiply instruction
3. multiply and divide instructions
4. short word length

7-16. A stack is a/an
1. type of computer complex
2. arithmetic unit with multiple registers
3. series of I/O devices
4. temporary storage area for frequently accessed data

7-17. Refer to figure 8-6. Which of the following are examples of instructions that use (a) the single operand and (b) the double operand formats?
1. (a) Add (b) clear
2. (a) Rotate (b) subtract
3. (a) Compare (b) shift
4. (a) Move (b) multiply

7-18. How many methods of addressing may be used on the PDP 11/45?
1. 1
2. 2
3. 8
4. 4

7-19. Which of the following describes the autoincrement addressing mode?
1. Postincrement, 1 for word and 2 for byte
2. Preincrement, 1 for word and 2 for byte
3. Postincrement, 1 for byte and 2 for word
4. Preincrement, 1 for byte and 2 for word

7-20. Compared to most computers, what is unique about the index mode of addressing used by the PDP 11/45?
1. Length of index register, 16 bits
2. Number of index registers, 16
3. Location of index word (memory vice register)
4. Type of index word (binary vice octal)

7-21. What PDP 11/45 addressing mode allows the user to write position independent coding?
1. Absolute
2. Relative
3. Relative-deferred
4. Program counter

Learning Objective: Relative to interfaces in simulator systems, point out the need for them, their components, and the operational methods employed with them.

7-22. The boundary between the digital computer and the training vehicle is called an interface.

7-23. Which of the following statements is correct regarding the signals processed by an interface?
1. The signals processed must include digital input signals
2. The signals processed must include analog output signals
3. The signals processed must include analog and digital signals
4. The signals processed can include analog and digital input/output signals

- In the upper right hand corner of figure 8-7 is a list of the major routines of a program (basic instrument flight) that has been written for the DDP-124 computer. Every 50 milliseconds, the complete simulation program for Device 2B21 is executed. A detailed explanation of this routine is given in the text.

7-24. What are the basic components of an interface system?
1. D/A, A/D, D/O, and D/I converters
2. Input buffer, output buffer, and converters
3. Computer, I/O buffer, and converters
4. I/O buffer, timing and control unit, address counter and decoder, and data converters

7-25. Which of the components found in an interface system is used to compensate for differences in rate of flow of data?
1. Converter
2. Address counter and decoder
3. I/O buffer
4. Timing and control

7-26. Since the length of the DDP-516 computer word is 16 bits, you normally would expect to find an I/O buffer with a capacity of
1. 8 bits
2. 16 bits
3. 32 bits
4. 64 bits

7-27. Timing and control signals are generated in
1. the timing and control section only
2. the computer only
3. either the timing and control section or the computer
4. both the computer and the timing and control section

- Use the following alternatives for items 7-28 through 7-32.

1. Speed brake switch, trainee station (digital input)

2. Visual indication (light bulb) instructor station (digital output)

3. Throttle control, trainee station (analog input)

4. Air-speed indicator, instructor station (analog output)

7-28. How many different types of OCP commands are there?
1. 1
2. 2
3. 3
4. 4

7-29. OCP 40040 would be used to input a signal from--
1. 1
2. 2
3. 3
4. 4

7-30. OCP 40010 would be used to output a signal to--
1. 1
2. 2
3. 3
4. 4

7-31. OCP 40020 would be used to input a signal from--
1. 1
2. 2
3. 3
4. 4

7-32. OCP 40004 would be used to output a signal to--
1. 1
2. 2
3. 3
4. 4

- Refer to figure 8-8 in answering items 7-33 through 7-35.

7-33. Which of the following gates receives an input from all the OCP commands?
1. G
2. L
3. M
4. N

7-34. Which of the following statements is correct regarding gates C, U, and W?
1. They act as buffers
2. They invert the signal
3. They delay the signal
4. They shape the signal

7-35. The ENABLE I/O CHANNEL signal is set by (a) and reset by (b).
1. (a) $20\overline{D}$, OCP, and 10D
   (b) 21D, 23D, and 10D
2. (a) 24D, OCP, and 10D
   (b) 23D, 10D, and OCP
3. (a) 10D, 23D, and OCP
   (b) 24D, OCP, and 10D
4. (a) 20D, 10D, and 23D
   (b) 24D, 21D, and 10D

- Figure 7A is the timing diagram for analog outputs. For analog inputs, Cℓ 1 is not produced, and Cℓ 2 through Cℓ 6 are reduced 14 μsec. For digital inputs and outputs (DI, DO), Cℓ 1 and Cℓ 2 are not produced, and Cℓ 3 through Cℓ 6 are reduced 28 μsec. Timing and control circuits are covered in detail in Digital Computer Basics.

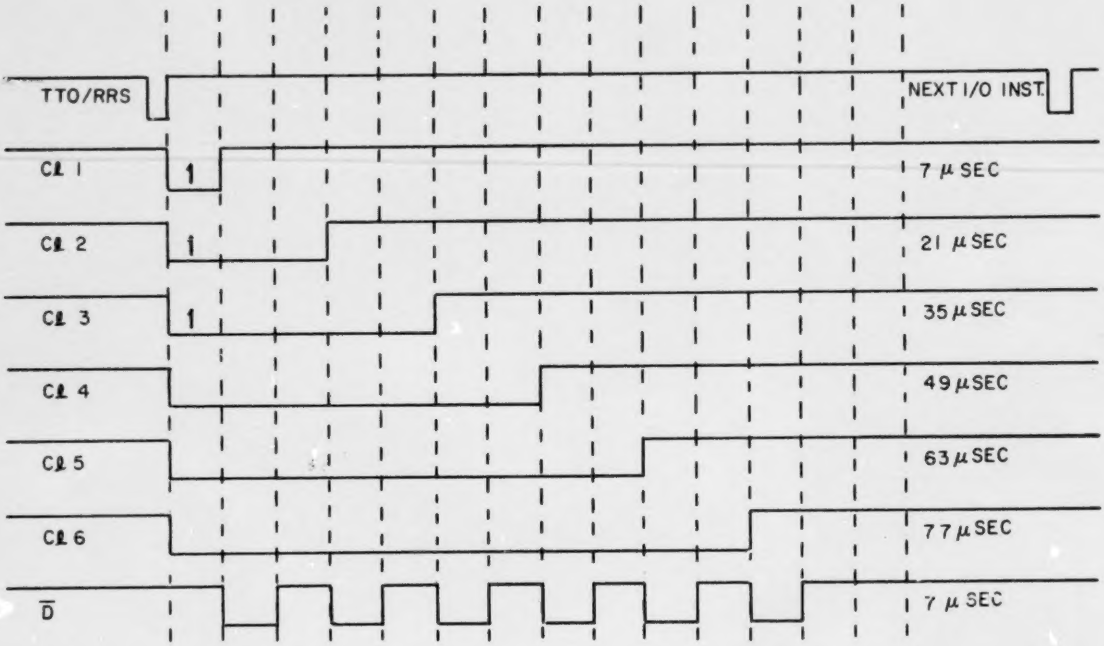

Figure 7A.--Timing diagram, analog outputs.

7-36. Which of the following indicates the correct timing relationship, in microseconds, for digital outputs?

	Cℓ 3	4	5	6
1.	7,	21,	35,	49
2.	14,	28,	35,	42
3.	21,	35,	49,	63
4.	35,	49,	63,	77

7-37. The timing pulse generator shown in figure 8-9 is the circuit used in Device 2B21.

- In answering items 7-38 through 7-41, use the following alternatives and refer to figure 8-9 in the text and to figure 7A in this course book.

1. All are set
2. A reset; B through F set
3. A and B reset; C through F set
4. A through C reset; D through F set

7-38. What is the initial (preset) condition of the register for analog outputs (AO)?
1. 1
2. 2
3. 3
4. 4

7-39. What is the initial (preset) condition of the register for digital outputs (DO)?
1. 1
2. 2
3. 3
4. 4

7-40. What is the initial (preset) condition of the register for analog inputs (AI)?
1. 1
2. 2
3. 3
4. 4

7-41. What is the initial (preset) condition of the register for digital inputs (DI)?
1. 1
2. 2
3. 3
4. 4

7-42. Refer to figure 8-9 in the text and to figure 7A in this course booklet. The output from gate H is true for
1. 7 µsec
2. 14 µsec
3. 21 µsec
4. 35 µsec

7-43. What advantage is derived from using X and Y steering signals in conjunction with different allow codes?

1. Increased speed of response
2. Reduced complexity in circuit design
3. Reduced number of required circuits
4. Increased reliability of circuit response

7-44. The input to the sexadecimal decoder consists of address counter

1. outputs 2^0 and $\overline{2^0}$ through 2^3 and $\overline{2^3}$ only
2. inputs of $\overline{D}$ and $\overline{C\ell 6}$
3. outputs 2^4 and $\overline{2^4}$ through 2^7 and $\overline{2^7}$ only
4. outputs 2^0 and $\overline{2^0}$ through 2^7 and $\overline{2^7}$

X0 = $\overline{2^0}\ \overline{2^1}\ \overline{2^2}\ \overline{2^3}$

X1 = $2^0\ \overline{2^1}\ \overline{2^2}\ \overline{2^3}$

X2 = $\overline{2^0}\ 2^1\ \overline{2^2}\ \overline{2^3}$

.
.
.
.

X15 = $2^0\ 2^1\ 2^2\ 2^3$

Y0 = $\overline{2^4}\ \overline{2^5}\ \overline{2^6}\ \overline{2^7}$

Y16 = $2^4\ \overline{2^5}\ \overline{2^6}\ \overline{2^7}$

Y32 = $\overline{2^4}\ 2^5\ \overline{2^6}\ \overline{2^7}$

.
.
.
.

Y160 = $\overline{2^4}\ 2^5\ \overline{2^6}\ 2^7$

Figure 7B.--X and Y steering signals.

- Refer to figure 7B in answering items 7-45 through 7-47.

7-45. Which of the following correctly describes the X2 Y32 steering signal?

1. $\overline{2^0}\ \overline{2^1}\ \overline{2^2}\ \overline{2^3}$, $\overline{2^4}\ \overline{2^5}\ \overline{2^6}\ \overline{2^7}$
2. $2^0\ \overline{2^1}\ \overline{2^2}\ \overline{2^3}$, $2^4\ \overline{2^5}\ \overline{2^6}\ \overline{2^7}$
3. $\overline{2^0}\ 2^1\ \overline{2^2}\ \overline{2^3}$, $\overline{2^4}\ 2^5\ \overline{2^6}\ \overline{2^7}$
4. $2^0\ 2^1\ \overline{2^2}\ \overline{2^3}$, $2^4\ 2^5\ \overline{2^6}\ \overline{2^7}$

7-46. Which of the following correct describes the X14 Y144 steering signal?

1. $\overline{2^0}\ \overline{2^1}\ \overline{2^2}\ 2^3$, $2^4\ 2^5\ 2^6\ 2^7$
2. $2^0\ \overline{2^1}\ \overline{2^2}\ \overline{2^3}$, $2^4\ 2^5\ 2^6\ 2^7$
3. $\overline{2^0}\ 2^1\ 2^2\ 2^3$, $2^4\ \overline{2^5}\ \overline{2^6}\ 2^7$
4. $2^0\ \overline{2^1}\ \overline{2^2}\ \overline{2^3}$, $\overline{2^4}\ 2^5\ 2^6\ 2^7$

7-47. Which of the following, if any, correctly describes the X7 Y84 steering signal?

1. $2^0\ 2^1\ 2^2\ \overline{2^3}$, $2^4\ 2^5\ 2^6\ 2^7$
2. $\overline{2^0}\ 2^1\ 2^2\ 2^3$, $\overline{2^4}\ \overline{2^5}\ 2^6\ \overline{2^7}$
3. $\overline{2^0}\ 2^1\ 2^2\ \overline{2^3}$, $2^4\ \overline{2^5}\ 2^6\ \overline{2^7}$
4. Since the Y signals are formed in increments of 16, there is not an X7 Y84 signal generated

- Refer to figure 8-11 in answering items 7-48 and 7-49.

7-48. The A/D converter used in Device 2821 outputs

1. ±10 volts
2. ± 5 volts
3. a 10-bit digital word
4. an 11-bit digital word

7-49. What is the significance of a zero output voltage from the comparator?

1. The output from the D/A converter is larger than the unknown analog voltage
2. The output from the D/A converter is smaller than the unknown analog voltage
3. The comparator is not operating properly
4. The digital output is a correct representation of the scanned analog voltage

- Refer to figure 8-12 in answering items 7-50 and 7-51.

7-50. What control signals regulate the input and output from the D/A converter used by Device 2B21?

	Input	Output
1.	TA	Allow analog codes only
2.	TA	Allow analog codes, and X and Y steering
3.	Allow analog codes	TA
4.	X and Y steering	TA

7-51. The A/D converter outputs an 11-bit word, whereas the D/A converter accepts a/an
1. 10-bit word
2. 11-bit word
3. 12-bit word
4. 24-bit word

7-52. The transfer process whereby both the assertion and negation signals are sent is called a
1. parallel transfer
2. serial transfer
3. summation transfer
4. jam transfer

7-53. Which of the following circuits has been designed to overcome the problem of maintaining an output analog voltage between periodic digital updating signals?
1. D/A converter
2. A/D converter
3. Sample/hold
4. Summation network

Refer to figure 8-13. Select from column B the circuit component(s) that perform(s) each sample/hold function listed in column A.

	A. Functions	B. Components
7-54.	Input switch	1. Q3, Q4, Q5
7-55.	Storage	2. C1
7-56.	Holding amplifier	3. Q1, Q2
		4. C2

Learning Objective: Recognize the types and functions of typical student stations and instructor consoles.

7-57. To qualify as a training vehicle, what function(s) must be provided by a training device?
1. Instructor/student stations must be physically connected
2. It must provide the proper environment only
3. It must provide for instructor control only
4. It must provide both the proper environment and instructor control necessary for training to take place

7-58. Refer to figure 8-15. An analog signal will be present on the output of the AND gate for what length of time? (Hint: See figure 8-10 and 7A. Remember, this is an analog input.)
1. 7 μsec
2. 14 μsec
3. 63 μsec
4. 77 μsec

7-59. The ultimate form and destination of data that results from a throttle movement is
1. an analog voltage sent to a gauge
2. an analog voltage felt on a pot
3. a digital word stored in memory
4. a digital word sent to a decade counter

7-60. How many analog inputs are there in Device 2B21?
1. 1
2. 2
3. 51
4. 52

7-61. When is the output of the sample and hold card that represents manifold pressure present?
1. Only when the computer is outputting analog information
2. Only when the computer is not outputting analog information
3. Always under normal operating conditions
4. Only when the sample and hold card is receiving an input

7-62. Refer to figure 8-17. Signal DI10 is composed of signals
1. allow digital inputs, X10 and Y'0
2. allow digital inputs, X0, and Y'0
3. allow digital outputs, X10, and Y'0
4. allow digital outputs, X0, and Y'0

7-63. Signal DO5 is composed of input signals
1. allow digital outputs, X5, and Y'0
2. allow digital outputs, X0, and Y5
3. allow digital inputs, X5 and Y'0
4. allow digital inputs, X0 and Y5

Learning Objective: Point out how a flow chart is used to explain the operation of a simulator system.

7-64. A control system that processes data such that the answers obtained are useful in controlling the same process is called a/an
1. analog system
2. digital system
3. real time system
4. feedback system

7-65. Which of the following organizations is responsible for the specifications of the software that accompanies each training device?
1. NTEC
2. CNET
3. CNETS
4. Contractors

A. Main Trainer program

B. DDP-124 Programmer's manual

C. Daily Readiness Check program

D. DDP-124 Maintenance manual

E. Trainer System Utility program(s)

F. Trainer System Test program(s)

G. DDP-124 Interface manual

Figure 7C--Software.

- In answering items 7-66 through 7-68, refer to figure 7C.

7-66. Which of the following programs/manuals belong to the "commerically available" category?
1. A, C, E, and F
2. B, D, and G
3. E, F, and G
4. All of them

7-67. Which of the following programs/manuals belong to the "contractor provided" category?
1. A, B, C, and G
2. A, C, E, and F
3. C, D, F, and G
4. B, D, and G

7-68. The Deep Submergence Rescue Vehicle (DSRV) simulator has a program written for the XDS-930 Computer that is based on algorithms describing the real world vehicle. What is this program called?
1. F
2. E
3. C
4. A

7-69. As depicted in figure 8-19, the main trainer program consists of modules or major routines that include
1. the simulation routines only
2. an analog and digital I/O routine only
3. a wait-for-interrupt routine only
4. all of the above routines

- Items 7-70 through 7-73 relate to Device 2B21.

7-70. Describe the Real Time Clock used by the device.
1. It is an electromechanical device used to time the length of the main trainer program
2. It is an electronic device, a one-shot multivibrator, used to time the waste-time routine
3. It is an electronic device, a one-shot multivibrator, that provides the 50-millisecond iteration rate for the main trainer program
4. It is an electromechanical device used to time the individual modules of the main trainer program

7-71. When the test-for-error-flag is executed, it is found to be set and the computer halts. What does this mean?
1. The time allotted for the previous execution of the major simulation subroutines has been exceeded
2. The program is functioning normally
3. The values computed for the synchros are in error
4. One of the error-sense switches has been set

7-72. The two subroutines within the executive routine are the
1. MRC and Real Time Clock
2. "Computations" for the synchros and the MRC
3. "Computations" for the synchros and the Real Time Clock
4. Senses switch and MRC

7-73. Refer to figure 8-20. A memory test program will be performed during a run of the executive routine if
1. sense switch #5 is set and the MDU is connected
2. sense switch #5 is set and the MDU is disconnected
3. sense switch #6 is set and the MDU is connected
4. Sense switch #6 is set and the MDU is disconnected

7-74. Most of the new, main trainer programs are characterized by the presence of a/an
1. synchro subroutine
2. sine/cosine subroutine
3. executive routine that incorporates all the program modules
4. executive routine that controls/directs the simulation modules

7-75. Device 2B21 employs a "search for nearest station" routine as an idle or waste time routine. The equivalent subroutine in Device 21B56D is entitled
1. Call Cab A Subroutine
2. Call Cab b Subroutine
3. Checksum Core
4. Idle

Assignment 8

Digital Systems Troubleshooting

Text: Pages 190-215

Learning Objective: Recognize microelectronic circuit types, methods of packaging, and some failures sustained in these type circuits.

8-1. The two basic approaches to microelectronic circuit design are
1. active and passive elements
2. diffusion and evaporation
3. monolithic integrated circuits and film circuits
4. thin and thick film circuits

● The following terms should be used while answering items 8-2 and 8-3.

A. Diffused planar

B. Evaporation

C. Active components

D. Active and Passive components

E. Passive components

F. Silk-screen

8-2. Which of the terms are used in describing monolithic circuit construction?
1. A, D, and B
2. A, C, and B
3. B, E, and F
4. F, E, and A

8-3. Which of the terms are used in describing film circuit construction?
1. A, D, and B
2. A, C, and B
3. B, E, and F
4. F, E, and A

8-4. In hybrid microelectronic circuits, what process is used to form (a) the active and (b) the passive components?
1. (a) diffused planar (b) diffused planar
2. (a) evaporation (b) evaporation
3. (a) diffused planar (b) evaporation
4. (a) evaporation (b) diffused planar

8-5. Which of the following is a correct comparison between a conventional circuit and an integrated circuit J-K flip-flop?
1. 40 separate elements versus 10
2. 40 hermetic seals versus 10
3. 300 separate processing operations versus 30
4. 200 connections versus 20

8-6. Which of the following factors can be used to control the concentration of impurity atoms that are diffused into a silicon wafer?
1. Type of impurities
2. Temperature of the oven only
3. Time in the oven only
4. Both the temperature of the oven and the time the wafer spends in the oven

8-7. Which of the following statements is correct concerning the silicon slice shown in figure 9-4?
1. It contains 500 different types of circuits
2. Each of the 500 identical circuits may contain up to 50 elements
3. It can contain diffused elements such as resistors, inductors, and capacitors
4. Of the circuit elements shown, the 1K resistor requires the most total area

8-8. During integrated circuit slice processing, where are the circuit elements formed?
1. In areas where the silicon oxide is left on the surface
2. In areas where the silicon oxide is removed from the surface
3. In the silicon oxide
4. In the masks

8-9. The substrate material most commonly used for thin- and thick-film circuits is
1. oxidized silicon
2. glass
3. silicon
4. ceramic

8-10. What is the primary advantage of hybrid microcircuits over other microcircuits?
1. Size
2. Speed
3. Design flexibility
4. Reliability

8-11. Which of the following integrated circuit packaging methods has evolved from that used for transistors?
1. Oval flat pack
2. Circular flat pack
3. DIP
4. Modified TO-5

8-12. What was the primary reason for the development of the dual-in-line packaging method?
1. To simplify construction
2. To reduce construction costs
3. To overcome design problems
4. To overcome handling problems

Learning Objective: Point out characteristics of digital integrated circuits, including voltage and noise levels, operating speed, and the fan-in/fan-out feature, and recognize logic families formed with these circuits.

- Refer to figures 9-10 and 9-11 when answering items 8-13 and 8-14.

8-13. What is the effect, if any, on the output logic voltage level of T1, when the logic circuits are connected in cascade?
1. Nothing, logic voltage levels remain the same
2. Output voltage is reduced to a swing of 0.2 volt to V_{CE}
3. Output voltage is amplified
4. Output voltage is reduced to a swing of 0.2 volt to 0.9 volt

8-14. What defines (a) the '0' state and (b) the '1' state of this simple direct-connected circuit?
1. (a) Collector saturation voltage V_{CE}
   (b) base saturation voltage V_{BE}
2. (a) Base saturation voltage V_{BE}
   (b) collector saturation voltage V_{CE}
3. (a) Emitter saturation voltage V_{EC}
   (b) collector saturation voltage V_{CE}
4. (a) Emitter saturation voltage V_{EC}
   (b) base saturation voltage V_{BE}

8-15. A voltage level at the input to a logic circuit which causes the circuit to change states is called
1. logic voltage
2. noise margin
3. voltage margin
4. threshold voltage

8-16. The difference between the operating input logic voltage level and the threshold voltage is called the
1. operating speed of the circuit
2. noise margin of the circuit
3. power dissipation of the circuit
4. operating voltage of the circuit

In items 8-17 through 8-20, select from column B an IC characteristic that fits each description listed in column A.

	A. Descriptions	B. Characteristics
8-17.	Ability to withstand short, transient voltage pulses	1. Operating speed
8-18.	Time required to charge/discharge capacitive elements	2. AC noise immunity
8-19.	Maximum number of circuits a logic gate is capable of driving.	3. Fan-out
8-20.	Power required to operate with a 50% duty cycle	4. Power dissipation

---

8-21. The maximum temperature at which a silicon transistor can perform satisfactorily is
1. +125° C
2. +100° C
3. -50° C
4. +200° C

In items 8-22 through 8-25, select from column B the identifying feature of each logic family listed in column A.

	A. Families	B. Features
8-22.	TTL	1. Combination of transistor types (N-P-N, P-N-P)
8-23.	DTL	2. Diodes
8-24.	ECL	3. Multiemitter transistors
8-25.	CTL	4. Common-emitter resistor coupling

8-26. Which of the following logic equations describes the output from the circuit shown in figure 9-12 (B)?
1. ABC = '1'
2. $\overline{A}BC$ = '1'
3. $A\overline{B}C$ = '1'
4. $\overline{ABC}$ = '1'

8-27. Which of the following properly describes the order of diffusions in a monolithic TTL transistor?
1. Collector, base, emitters
2. Base, collector, emitters
3. Collector, emitters, base
4. Base, emitters, collector

8-23. What is the function of transistors T3 and T4 shown in figure 9-13 (A)?
1. Push-Pull amplification
2. Push-Push amplification
3. Provides current gain drive for switching in both directions
4. Provides inversion for proper NAND operation

8-29. Refer to figure 9-14. What function is served by transistor T4?
1. It is the logic input transistor
2. It isolates the input from the output
3. It provides the reference voltage level for the circuit
4. It amplifies the output

8-30. Why is it difficult to precisely define the logic states in an ECL circuit?
1. V_{BB} is not defined
2. V_{Ce} is not defined
3. V_{in} is variable
4. The transistors never go into saturation

8-31. The complementary-transistor logic circuits are easily identified by their
1. employment of two types of transistors
2. high switching speed
3. high fan-out
4. high input impedance

8-32. Refer to Table 9-1. Which of the following logic families have the highest power consumption?
1. ECL and CTL
2. ECL and TTL
3. CTL and TTL
4. TTL and RTL

Learning Objective: Recognize aspects of integrated circuit troubleshooting, and of test equipment designed exclusively for digital troubleshooting.

8-33. One of the important differences between circuits built from discrete components and those built from digital ICs is the
1. ease with which the components of an IC circuit can be checked
2. inaccessability of the IC components
3. inaccessability of the analog components
4. complexity of the characteristics of the analog components

8-34. "Stimulation and observation of multiple inputs and outputs" describes the troubleshooting techniques required for
1. all digital circuits
2. all analog circuits
3. most analog circuits
4. digital integrated circuits

8-35. Refer to figure 9-18. Which of the following correctly describes a high logic state?
1. A voltage level between 0.4 V and 2.4 V
2. Any voltage above 0.4 V
3. Any voltage below 2.4 V
4. A voltage level above 2.4 V

8-36. Why has it been necessary for the IC troubleshooter to cut the circuit traces or pull the leads in order to troubleshoot TTL circuits?
1. Insufficient power of conventional signal injectors
2. High output impedance of circuits under test
3. High frequency of circuits under test
4. Low frequency of circuits under test

8-37. Which of the following terms can be used to categorize the failures found in digital IC circuits?
1. Opens and shorts
2. Inputs and outputs
3. External and internal
4. Components and interconnections

8-38. When used in conjunction with TTL logic circuits, what is meant by the term "floating"?
1. It describes the logic level of an input that is not connected
2. It is a term used to describe the construction of the logic leads
3. The logic 1's and 0's are designed to float around a given voltage
4. The output logic levels rise or "float" to maximum level

● Use the internal IC failures listed below as the alternatives for items 8-39 and 8-40.

1. An open bond on either and input or an output

2. A short between an input or an output and V_{CC} or ground

3. A short between two pins (neither of which is V_{CC} or ground)

4. A failure in the internal circuitry

8-39. The logic level will float with
1. 1
2. 2
3. 3
4. 4

8-40. Simultaneous high or low input signals will operate the circuit normally if the failure is
1. 1
2. 2
3. 3
4. 4

8-41. Which of the following IC failures can cause the upper transistor of the output totem pole to lock in the high state?
1. Short to V_{CC}
2. Short between two pins
3. Open input
4. Internal "steering circuitry"

In answering items 8-42 through 8-44, select from column B each digital test equipment described in column A.

	A. Descriptions	B. Equipments
8-42.	Outputs from a good device are matched with a device under test	1. Logic Analyzer
		2. Logic Probe
		3. Logic Pulser
8-43.	Gives a direct read-out of logic level wherein half-brightness means no signal	4. Logic Comparator
8-44.	Used to modify logic states	

8-45. A glitch is a low frequency interference signal that can be extremely difficult to detect. Which of the following digital test equipments can display glitches?
1. State analyzer
2. Logic-timing analyzer
3. Logic-trigger generator
4. Logic comparator

Learning Objective: Relative to troubleshooting digital equipment, recognize the systematic approach to analyzation, and the step-by-step procedure with test equipment to effect trouble isolation.

● Items 8-46 through 8-50 relate to training vehicle troubleshooting.

8-46. Once you have determined that a malfunction does exist, a good "first-check" is the
1. I/O buffer
2. operation of the student station
3. power supplies
4. instructor station instruments

8-47. After a quick check of the power supplies, what is the next step in the localization of a malfunction on a digital training device?
1. Run the CPU test
2. Observe training vehicle performance
3. Start signal tracing
4. Run the daily readiness check

8-48. Which of the following symptoms would point to the computer as being the malfunctioning section?
1. Parity errors only
2. Program tape will not load only
3. Either 1 or 2 above
4. Trainer will not "freeze"

8-49. The speed indicator (analog device) is failing. What are the probable malfunctions under conditions where (a) it is the only analog output failing, and (b) all other analog outputs are failing?
1. (a) sample/hold card (b) D/A converter
2. (a) D/A converter (b) D/A converter
3. (a) timing circuit (b) sample/hold card
4. (a) A/D converter (b) D/A converter

8-50. What is the proper sequence of steps used to troubleshoot a malfunctioning training device?
1. Localize, Analyze, Isolate
2. Analyze, localize, Isolate
3. Isolate, Analyze, Localize
4. Localize, Isolate, Analyze

● Refer to table 9-2 in answering items 8-51 and 8-52.

8-51. Which of the following statements is correct concerning the use of diagnostic routines to troubleshoot/isolate trainer malfunctions?
1. They can be performed on-line or off-line
2. They provide for a flexible attack
3. The check is automatic
4. They require skilled techniques

8-52. Which of the following statements is correct concerning the use of signal tracing to isolate trainer malfunctions?
1. Rapid checkout is provided
2. Rigid constraints are imposed
3. Hard-copy quality control is provided
4. Precise and final results are obtained

● Substitution maintenance (replacing a suspected bad card with a good one) is generally the quickest way a device can be brought on-line.

8-53. How is the majority of conventional troubleshooting time spent?
1. Looking at diagnostic printouts
2. Repairing power supplies
3. Looking at good signals
4. Replacing bad boards

8-54. One of the problems encountered with the use of a comparator is
1. a false indication because of poor clip contact
2. lack of high frequency response
3. voltage limitations of the clip
4. interpretation of the readout display

8-55. Another name for the first step in the digital troubleshooting algorithm is
1. mapping
2. isolating
3. analyzing
4. eliminating

8-56. The test for an open output bond in an IC driver indicated this was not the failure. The next test is for a/an
1. short between two nodes
2. open input bond
3. short to V_{CC} or ground
4. failure of the internal circuitry of the IC

8-57. If you simultaneously pulse and probe a node and get a steady "high" state, this indicates a/an
1. short to ground
2. open output bond
3. short to V_{CC}
4. open input bond

8-58. Which of the following will cause you to suspect an open signal path in the circuit external to an IC?
1. The logic comparator indicates a failure external to the IC
2. Excessive heat is radiating from an IC package
3. The logic comparator failed to indicate a malfunction and the circuit is failing
4. The logic probe indicates a high level on an input node

8-59. Which of the following statements is correct concerning the application of a logic probe to the problem of open signal paths?
1. Logic probes cannot be used to detect open signal paths
2. Logic probes must be used in conjunction with logic pulsers
3. Logic probes must be used in conjunction with an ohmmeter
4. Logic probes can both detect and locate open signal paths

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